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# PRESIDENT'S MESSAGE

## Prestige and a Progress Report

By E. L. Slagle

*President, American Institute of Industrial Engineers*

This message comes in two parts: (1) a discussion of professional prestige; and (2) a report.

To my way of thinking, prestige and progress are inseparably related, and it seems logical to me to cover both subjects at this time.

### Part I. Engineering and Prestige

We all recognize that pride is a basic motivating force of considerable importance. It is safe to say that even monetary rewards take a back seat to pride. We all seek the respect of our associates both on and off the job.

It is also well recognized that pride is a basic human weakness. In my message, appearing in the July-August, 1955, issue of THE JOURNAL OF INDUSTRIAL ENGINEERING, I discussed the need for organization and the proper objective of a professional organization. You may recall that one of the points made was . . . "organization stems from need—not the need of the group members, but, rather, the need of the people they serve. If we should lose sight of this, if we proceed on a self-serving basis, we will no longer progress—or exist as a group." It is not my intention, however, to dwell here upon this thought. We could, however, benefit from a consideration of pride and prestige and the impact of these forces upon industrial engineering.

Prestige, group or individual, must stem from either the nature of the service performed, from achievement, or from both.

Certain groups or professions have already earned a high degree of respect, either through the service they perform or their record of achievements. Religious leaders devoted to spiritual progress are an example of this. The medical profession has earned the respect and admiration of all of us due to their high ideals and standards, their achievements, and their efforts affecting our health and length of life. Academicians, too, have earned a high level of respect since the accumulation of knowledge is more important to them than the accumulation of material things. The legal profession has earned a similar status since the lawyer deals with justice and since, through organized efforts, a code of ethics has been established and maintained. It is quite natural that groups working with more material matters find prestige more difficult to attain. This difficulty, no doubt, stems at least in part from the fact that a fair percentage of the individuals engaged in the science of useful arts or technology demonstrate more interest in personal progress than in human progress. It is not my intent here to convert industrial engineers to a more altruistic point of view; the point is made to assist us in an analysis of our situation and to assist us in our efforts to do a better job.

When any group of people are not satisfied with a situation, they can, by their reaction, be categorized into one of the following three sub-groups:

1. The do-nothings;
2. The complainers;
3. The doers.

This latter category may be further broken down into the schemers and builders.

In the do-nothing category are the individuals not en-

gaged in any pursuit other than that necessary to maintain life. These individuals are not working with civic, religious, or professional organizations; they build nothing, they leave nothing, they lack even the interest to graduate into the second category—the complainers.

Complainers are normally very active although they accomplish nothing except possibly to irritate and obstruct the individuals trying to effect a change in the right direction. The complainers will not be found devoting their time to the work of technical or other committees. They spend no time gathering facts. They do not attend business meetings unless they have a beef. The airing of grievances and "living" (as they call it) are pastimes preferred to the reading of trade journals, editorials (if you are reading this, you are not, in all probability, in this category), textbooks, or constitutions and by-laws. It is always easy to spot such an individual since, in addition to a complaining attitude, it will be noted that he: (1) avoids contributing to worthy causes (he has inside information on the misuse of funds); (2) he does not vote (he knows there is no purpose in voting since "they" have everything rigged in advance); and (3) he belongs to no civic group (he is wise to all those glory grabbers). This fellow is a real problem. The do-nothing is simply dead weight; the complainer spends his time greasing the pole which must be climbed by the doers.

Fortunately, a large percentage of any group is in the doer category. With the best of intentions many individuals, seeking to find a quick solution to the problem of prestige, do more harm than good. They seek to achieve, through publicity, lots of activity, and a well packaged product (black leather bindings and gold leaf lettering), a position which will accrue to them only as a result of real achievements. Activity, simply for the sake of activity, is pointless. We cannot make real progress on a get-rich-quick approach or through the use of carnival barkers.

From this analysis evolves the path the American Institute of Industrial Engineers must follow if it is to establish and maintain industrial engineering on a professional level. We will achieve the respect and prestige we seek when we have behind us a record of substantial service to the community—when we have demonstrated that our objectives and standards are more than words on a piece of paper.

In these days of early development of our organization, let us not lose sight of this fundamental. Let us remember that as engineers we require facts, objectivity, and a broad perspective before we present a report, or complain, or vote, or do nothing.

## Part II. Progress Report

### A. Ithaca Meeting

As you no doubt know, there was a meeting of recognized leaders of the industrial engineering field in St. Louis, Missouri, on May 13, 1955. The purpose of this meeting was to review in a general manner the purpose, direction, and progress of the American Institute of Industrial Engineers and industrial engineering and to advise and recommend to the American Institute of Industrial Engineers paths leading to the proper discharge of the responsibilities of our organization. This group met once again at Ithaca, New York, on October 20 and 21, 1955. At this meeting we reviewed such matters as:

1. A definition of industrial engineering.
2. The role of the professional.
3. The development of professional industrial engineers.
4. Industrial engineering research.
5. Industrial engineering publicity.

A report of this meeting will be published in the JOURNAL in the near future. One item of immediate interest to you is the definition of industrial engineering agreed upon by this Special Advisory Committee (see back cover).

It was further agreed that a universally acceptable definition would never be found, a definition would require refinement from time-to-time, and a definition of industrial engineering is essential at this time.

### B. Board of Trustees Meeting

A meeting of the Board of Trustees was held in Columbus, Ohio, on October 22, 1955. This issue of THE JOURNAL OF INDUSTRIAL ENGINEERING carries the minutes of this meeting. Minutes will be published following each such meeting. I urge you to read them and direct your comments or questions to your Vice-President, the Board Members-at-Large, or the President.

Of particular interest at this latest Board meeting were:

(1) The adoption of a policy permitting financial assistance of conferences; and existing policy providing for coordination of conferences was reviewed and reaffirmed. In previous messages I have discussed the need for such action. So many conferences bearing the AIIE label are being presented that we are certain to run into scheduling conflicts (there has been trouble on this already) and we are certain to have conferences which do not do credit to our organization. This latter difficulty can be avoided if our information is pooled and if the program content is reviewed by some one agency for general acceptability. Financial assistance for regional conferences has been requested, and Board action clears the way for such assistance.

(2) The adjustment of dues and fees. This matter has been reviewed with you in my previous messages and in my recent letter. This Board action represents a major step forward and the passing of a significant milestone—we are no longer devoting the majority of our time to problems of growth and organizational development.

(3) A change in the composition of the nominating committee. This, of course, requires a constitution change. Our present constitution (November, 1955) establishes the Vice-Presidents as the nominating committee. This arrangement has been found unsatisfactory and awkward since (1) the Vice-Presidential ranks are a very good source of Presidential nominees, and (2) the Vice-Presidents are reluctant to nominate themselves.

# Timestudy and Incentive Clauses in Union Contracts[1]

**By Phil Carroll**[2]

*Professional Engineer*

Let me take as my text the Eleventh Chapter, 23rd Verse from the book, according to Alexander Heron, "No Sale—No Job." I recommend the book to you for your own consumption. Harper & Brothers published it in 1954.

"What can be done to injure sales by raising the cost (he refers to wage rates) of the day's work too high can be done just as definitely and just as promptly by making the val ue (he refers to productivity) of the day's work too low."

Considering timestudy and incentive clauses, we've got enough to fill many, many books. They cover almost all of the procedures there are. Some are straightforward attempts to set down the ground rules. Clauses like that might read something like: "The standard will be set so that a normal, qualified employee, while working at the expected incentive pace, should earn X per cent (say, 25 per cent)."

Then there are many clauses related to the mechanics of timestudies. Examples are: How many studies you can take; how many watch readings you can throw out; and how to figure the average time.

At the other extreme, there are some clauses that are very damaging to industry, to the job security of the very employees these clauses were designed to protect. An example might be: "A standard may be changed only when there is a 25 per cent change in the method."

And here is the most unusual one I have seen: "If an agreement on a disputed time study cannot be reached between representatives of the time study department and the time study steward, the matter shall be referred to the time study department of the international union, whose decision shall be final and binding on both the company and the union." How would you like to have that one in your contract?

Why so many of these clauses? One point of view is that of encroaching on management—the union's taking a more active part in controlling the destinies of their members. My way of expressing it: "Sharing the fruits of industry at the source."

[1] Based on a talk before the National Foundry Association's 56th Annual Meeting in Chicago on October 7–8, 1954.

[2] Author of "Timestudy for Cost Control," "How to Chart Timestudy Data," "Timestudy Fundamentals for Foremen" and "Foremen Can Control Costs."

You can look at this variety in some other ways. One has to do with the installation of timestudy and incentives. We can say that a company may have many of its clauses inserted if it is installing a plan. The installation could be for the first time. It could also be, as a great many are, that of changing from one kind of an incentive system to another.

There is a different way to look at this array of clauses. To describe it, I use the simple word: "Confidence." I believe personally that confidence is inversely related to the length of the contract. You see this if you have studied those pamphlets entitled, "The Causes of Industrial Peace." Some of the most peaceful relations go on with very short contracts. The two examples that interested me most in the series were those of Hickey Freeman and Atlantic Steel.

There is a fourth view to this variety from my way of looking at it. You recognize that a great many of the ground rules are not written. Put the other way, it would take a book or two to cover all of them. The subject is further complicated by the political problems that are involved. With some unions you find that they won't do anything but grieve. They say in effect "Go ahead and do what you please. We will be judge and jury." Some refuse to take any kind of training. At the opposite extreme are those that insist upon the co-determination of piece work prices.

## Four Types

The subject is complex. I don't know that I can do much to unscramble it. But I will try to sort out some of the causes from the effects, and I will try to suggest some solutions. To discuss this subject I think we might put all of the clauses in an IBM sorting machine and bring them out into four piles:

1. One I would call "defining the plan or laying the groundwork."
2. Second I would call "the method of setting the standard," and under that some kind of a definition of a normal operator, or what is a "fair day's work."
3. Number 3 I would relate to the subject of changing standards, and under that I would have grievances and arbitrations.
4. The fourth I would call "non-incentive payments."

Groups 1 and 2—defining the plan and how to set the standards—overlap considerably. Many of us cannot define the plan. So what we do is to explain how we go about setting it up. With this goes what we describe as the fair day's work, or the normal operator. But I want to differentiate between these two types mentioned, because I want to discuss them separately.

I am assuming that we use timestudies and incentives together. You know that you are required to get union approval when you deal with incentives. That is because money is involved. But, as I understand it, approval is not required if you want to set standards for a fair day's work. However, we should agree that if you want to get any place, it is a lot better to have the union agreeing with you than disagreeing. That is not the same thing as mutual consent clauses. I suggest you agree before you start.

Establish the confidence beforehand. Without acceptance, you won't get any place anyhow. So work out your plan. Agree on what you are going to do. If you will do that you have no need for mutual consent clauses.

### Timestudy Manual

If you agree, I would like to offer my first suggested solution. Consider the method I saw in one company. First the company wrote a manual for its Timestudy Department. You might call yours "Industrial Engineering." Then the contract simply said, "We hereby adopt the manual" that had been set up.

We would agree that the ground rules should be defined. This is especially true if you are making a new installation. It is even more necessary if you are changing from one kind of a system to another.

### Employees' Handbook

Then you might go a step further and prepare a simplified explanation for your employees. It might be a very brief insert in your employees' handbook. You have seen many of these.

I believe that this is important, especially with new employees. I remember one plant where a highly successful installation went bad. We discovered when we ran down the cause that there had been considerable expansion and turnover. Thus our initial understanding had been cut down to about 50 per cent. So you see, it doesn't follow that once you set up a plan in good order, it will keep on running that way.

### Grievances

Then as I see it, you have to spell out the procedure for another reason. It is to prepare for grievances and arbitration. If too much is implied in your understandings, you have too much of "you did" and "you didn't." Also you have too much flexibility in the interpretations. In this connection, I think that any arbitrator you might seek should be a skilled engineer. I make the same recommendation for both timestudy-incentives and job evaluations. These are your two measuring sticks. You want to stick to facts, if you can. So keep away from the do-gooders.

### Measurement vs. Compensation

Right here you might say, "This can't be done." But I think there are better ways that many of us are not aware of. A part of our trouble comes from mixing money and time together. I call it "mixing compensation with work measurements." Piece work is our most common example. Too many of us think that incentive is a simple thing—just pay more money for more pieces. That is not work measurement. Besides, wage rates are changing. Wages have gone up and up.

Therefore, any part of timestudy that may be put into your incentive plan to offset low wages, you are going to pay for twice as your wages go up to the community level. No doubt you have heard of such things as industry-wide, community-wide bargaining. Who knows how far that will go.

Then also, too many so-called managers try to substitute timestudy and incentives for management, for supervision. Some think that more "bucks" will cure anything. That is like the thinking of the advocates of group incentive plans. I read their so-called advantages with my glasses on, and every one says to "pass management responsibilities over to the workman."

Too many of us think that these tools will solve problems—that they will reduce labor costs or open up production bottlenecks. Sure, good timestudy-incentives will do these things. But I think our objectives are quite different.

### Fair Day's Work

To me, what you are after is a measure of a fair day's work. You need that for some of the managerial controls other than those just described. You have to have a measure of output. You want a basis for proper costing and tons won't give it to you. You want to know where your profit leaks are, and most of our costs are not worth the paper they are written on. They are misleading and misguiding. You can't get correct cost facts out of a simple incentive plan.

So at this point I have a second suggestion. Stop mixing money with time. When you do, you can solve some of your problems. You can correct inequities by changing base rates, as you should. You can negotiate changes in whatever abortive clause you may have.

Separating time from money has another advantage. Under piece work, the time study man cannot win. No matter to what lengths he may go in trying to sell the employee he will hear, "Yes, but I don't make enough money." So I urge you to separate time from money. More importantly, you will get more correct costs. In my opinion, you cannot correctly apply overhead on a dollar basis.

### Setting Standards

Now let's discuss the second group clauses. I call these the "clauses related to the method of setting standards." Many of these grow out of what I call degrees of ignorance. We have every sort of timestudy-incentive plan in this country anybody could think of. Many varieties are cooked up by so-called consultants. Many variations result from our own plant methods of administration. We have a vast number of differences that grow out of what I call the "homemade plans." These are devised by the fellow with a little bit of information who starts tampering with the mechanisms.

We have a great many clauses that result from poor timestudy. Much of timestudy is poor because the man is untrained, underpaid and weak. As I said, in *Timestudy for Cost Control*, "The timestudy man is expected to be exact in his standards, skillful in method and plant layout, expert in feeds and speeds, a good mechanic and task demonstrator, a diplomat, and a salesman. If he gets paid more than a good foreman, he is at least a salesman." Isn't he?

### Poor Timestudy

In part, these conditions bring on many of the clauses related to the mechanics of timestudy. These we might divide into two parts. One part includes those clauses that have to do with setting the standards initially. The second group includes the clauses related to changing standards in order to keep them up to date.

Many clauses have to do with the mechanics of timestudy. They attempt, in clause after clause, to say what is a "fair day's work." Too many of them point to the "average man." An average man may be above or below the person who is qualified to give you a fair day's work. Some define how many watch readings, how many you can throw out, how long the study should be, and many other details.

### "Rate Setting"

My belief is that most of these clauses grow out of what I call "rate setting." By "rate setting" I mean the method where the "timestudy man" rushes out on the floor, takes a few watch readings and comes up with an answer. This method has several disadvantages. One is the quarrel about how fast the man worked while you took the study. Another is the question of what times are excluded. This latter is a different way of saying what method was incorporated in the time allowed? The third disadvantage is the personality clash. Somebody doesn't like the color of somebody else's necktie.

### Use Standard Data

That brings me to my third suggestion. Let me introduce it with a personal experience.

I remember discussing an incentive plan with a union expert in timestudy. He had five pages of clauses to "negotiate." As we went down through these, I came to one page, glanced at it and I turned the whole page over. At that he asked, "Why did you disregard all those clauses?" I said, "We propose to use standard data." No more arguments.

Standard data may be a new term to you. I will explain it by showing how it differs from ordinary timestudy. In simple explanation, you take a half bushel of timestudies. From these you build up standard element times that will cover all of the work of a type—molding, core making, casting cleaning.

By the way, many foundries have no measures in casting cleaning. Some use a tonnage basis. A great many plants treat it as indirect labor. All of these are mistakes. I would consider casting cleaning as direct labor. Oftentimes, it is more costly for certain castings than the molding plus the core making.

In a machine shop, your data might be built up on drilling, milling, lathes, and so forth. Build up all of the element standards for a type of work and, if I can persuade you, build up all of it for a type of work before you set any of your standards for that work. In this way, I think you get more consistent standards. You get a fairer measure of "What is normal skill."

You have a cost advantage, of course, in that the recorded information is used again and again. But the very fact that you use the same standards week after week establishes confidence between the management and the individual. Besides, data is a lot easier to explain. And you wash out the personality of the people involved if the standard data was built by a number of timestudy men.

So I suggest that you stop "rate setting," and go to standard data. This is one way to make many of the clauses unnecessary. Many don't even apply.

### Non-Incentive Payments

Standard data helps in a couple of other ways. One is to reduce the clauses I group in the fourth class. These have to do with the payment of average earnings. One contract I saw had eleven different provisions for paying average earnings. Another had sixteen.

Basically, I think this condition is often brought on by the failure on our part to set "rates on the job." Many times this happens because some irregular condition has grown up. The unions want to fix it, so we don't say, "We haven't got time to set a standard."

Much of this problem can be overcome by building standard data. Measure the irregular conditions. Don't refuse to take a timestudy because the job isn't running right. Don't try to remove the conditions before you take the timestudy, as is prescribed in all the "books."

Study what you find. Build up the standard data. Measure the irregular conditions because they will occur again. Then you can set standards from your data. You can reduce the demand for average earning. More importantly, you can put a dollar sign on what I call "management errors." I want to say more about that a little later.

### Changing Standards

Another way that data can help is in meeting the clauses I have grouped as "changing standards." This applies also to phases related to the administration of your incentive plan.

Many of these clauses were stuck in to protect against "rate cutting" and "speed-up." Here I am referring to actual "rate cutting," or actual "speed-up," not the automatic cry that you get. I am referring to the attempts to overcome the results of poor timestudy, trying to recover the loosening up some did to beat the Wage Stabilization Act, and the concealed method changes due to the elimination of work.

You have to make changes to avoid falling behind your competition. You will have method improvements forced upon you by outsiders—customers, competitors and equipment suppliers.

Many of these changes are easily made if you have standard data. This is true especially if you have been fair, if you have religiously allowed your employees for the added work caused by "management errors." But you can't agree to revise standards with some kind of a mutual consent clause. Nor can you agree to change only if there is "x" per cent change, like 25 per cent.

First, in revising standards, you must be fair with all of the people who are on incentive. You must be consistent. Secondly, you must make progress. Otherwise, eventually you will lose the business. Third, you must maintain a correct measure of your output. How else can you correctly apply your overhead?

### Expert Foremen

To help maintain fairness in standards, I think your foremen should be experts in timestudy. Then they know when conditions change. Then they should act like skilled timestudy men—either correct the conditions, or get extra time allowances. In this way, I believe, you can stop a great many grievances by correcting the conditions while the problem is in the complaint stage.

Now, remember, no system is going to solve problems. Thus, standard data is no automatic cure-all. You can mismanage it the same as anything else. You can fail to revise your standards. You can overlook the changes because "Negotiations are coming up next week," or "We are having an election," or we haven't got time, or something else.

### Over Payment

We talk about the problems of changing standards with method changes. But we use the wrong words. The problem is in trying to take away money from a fellow that he didn't earn, after we have been paying it to him for a while. Most arbitrators won't let you do it. So you have dozens of clauses that prohibit the practice.

Some clauses read about like: "The man shall make as much after the re-study as he did before." But did you ever see a clause that said how diligently he had to work to make as much as he did before? With only one side defined, you can "rate set" your company out of business.

### Suggestion Plan

Part of the problem of method change might be solved if we knew how to use suggestion plans. However, to be successful, I think we have to pay more than 10 per cent. I don't know what the right answer is any more than you. If I were asked, I would say that Mr. Lincoln is having pretty good luck with 50 per cent of the first year's savings. The question in my mind is, "Would we have better luck if we paid 100 per cent for six months?"

My point is twofold. One is to get your employees to help you maintain consistent standards. The other is to get your employees to contribute to the company's progress. Remember, "No Sale—No Job." That brings me to my concluding point.

### What Is Direct Labor?

Nearly everything I have said relates to mechanics of timestudy. You might think that I was like the managers who think only in terms of simple incentives. But I am not. Much more is involved. Do you recall that I mentioned costs and overhead several times? Whether you realize it or not, most companies figure costs by applying overhead to labor costs.

Therefore, I ask you, what is labor cost? What is direct labor? Suppose you go before an arbitrator and he says, "That standard isn't right. Add 10 per cent." Can that 10 per cent earn overhead? Suppose you pay average earnings because you haven't got a standard set for a job. Can that extra labor cost earn overhead? Thus, I suggest that you go one step further in your analysis of timestudy provisions. Look beyond these clauses for their effect upon your cost structure.

### Common Denominator

To figure production, we use labor time or money. That is because our products are mixed. We need a common denominator. Some foundries erroneously use pounds or tons. Pounds are way off. Just think a moment. More cores add work to castings. They usually add work to cleaning. They sometimes raise scrap. They often reduce yield. If you want to put it the other way, the more work you do to a casting, the less it weighs.

Many plants use labor time and money to figure cost. They think an hour or a dollar is the same as another hour or dollar. Then they uniformly spread the overhead with a shovel. But only good pieces can earn overhead. And you don't get more good pieces when you add something to the time or to the money that we call productive. You don't get more pieces when you neglect to reduce the standard time or money when you make an improvement. Besides, your costs stay high. You are not making progress competitively.

### Better Costs

In summary, then, you need good timestudies and incentives. You need them to get correct costs. In this

connection, I urge you to separate "management errors" from the so-called di ect labor. Toward that end, I suggest you stop "rate setting." Instead, build standard data from many studies. The data will give you more consistent standards. It will give what I think is the fairest measure of normal skill. That will remove the causes of many clauses.

Also, properly prepared data can greatly increase the amount of coverage by work measures. You can cover the specials and the short runs, especially the irregular conditions that occur—the "management errors." Coverage will remove many of the headaches of average earning clauses.

Also, data will help greatly in revising standards as methods change. This helps to offset clauses inserted to protect the so-called "accumulated skill."

But standard data will not overcome poor attitudes toward or lack of skill in timestudy. It won't overcome weak-kneed management and poor incentive administration. Not even a properly written policy and procedures manual will do that. The best plan you can install will fail with poor administration. You can't hope to have a timestudy man any better than you expect him to be, and dozens of clauses won't solve that problem either. You cannot legislate good human relations. None of these better methods will work without proper management.

**Good Management**

So will you agree with me, that timestudy and incentive clauses are not substitutes for good management? Put the other way, when you have good management, do you need the clauses?

And, as a conclusion let me quote a paragraph from a book that I think all of you might profit from reading. You may have seen parts of it as articles in Modern Industry—Dun's Review. The title of the book is *The Practice of Management* by Peter F. Drucker. On page 28 he says—"The management of any unionized company therefore needs definite long range objectives for its union relations. If it leaves the initiative in labor relations entirely to the union, it can be said not to manage at all. Unfortunately, that has been precisely the way too many of our managements have conducted their labor relations in the past fifteen to twenty years. They have left the initiative to the union. They have usually not even known what to expect in the way of union demands. They have, by and large, not known what the union is, how it behaves, or why it behaves as it does.

"When first told that certain union demands were about to be made, the typical management refuses to listen. It is sure the demand will not be made for the simple reason that it does not consider it justified. Then when the demand is made, management tends to turn it down as impossible or as certain to ruin the business, if not our free enterprise system.

"Three days to three years later management caves in, accepts the demand, and in a joint statement with the union leaders, hails the agreement as a milestone in democratic labor relations. This is not management. It is abdication."


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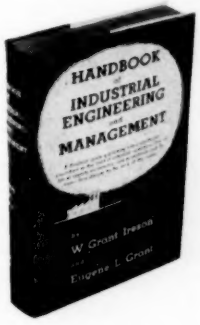


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# EDITORIAL COMMENTS

## It's Your Journal

The current issue of the JOURNAL is the third issue with the "new look." Your editor has been severely criticized for not having formally mentioned the changes that have been made. These changes should be obvious, but maybe a word or two is in order. All of these changes are part of a long-range development plan designed to provide an even better professional journal for you.

The basic objective of any professional journal could be simply stated as professional service. This has been our goal—service to the profession of Industrial Engineering and to the membership of AIIE. Thanks to your encouragement and support the JOURNAL has been able to grow and serve you.

The "new look" includes a radical change in format as well as several new features. The current issue has a new cover design. More pages have been added. We hope to continue expanding in both breadth and depth.

The format changes include use of larger and more readable type and a two-column page arrangement. The 8½" x 11" page size has been retained for the present, but a smaller size is being considered. These changes result in a more pleasing and more readable publication, as well as more adequate presentation of illustrative and mathematical material. The chances are that you have hardly noticed the change. A direct comparison of the present issue with the July-August issue will clearly indicate the magnitude of the format improvement.

The JOURNAL was directed to absorb the functions of the AIIE Newsletter this past July. The first batch of news material was included in the September-October issue in the form of chapter listings. The next issue included the "Institute Interests" feature, which will continue as a regular feature edited by Nelson K. Rogers. So far, chapter reporting of news items has been excellent. Complete minutes of the Board of Trustees' Meeting are included along with current news items in this issue.

One of the very popular new features is "Recent Readables" edited by George L. Anton. This feature is designed to help you keep informed of recent publications. It brings you selected references from many sources. These are compiled by Mr. Anton, with occasional aid from Editorial Board members. Perhaps you would like to send in brief abstracts of some of the interesting articles you uncover.

"Reader Comments" is a feature intended to give voice to discussion of previously published materials. Our readers have some very excellent comments, but most individuals seem to be reluctant about formally stating their opinions. We would like to hear from you.

The articles included in each issue are carefully selected to present a balanced coverage, subject to the limitations of available material. We attempt to include new developments in Industrial Engineering, research reports and stimulants to professional development, as well as articles concerning the everyday problems encountered by our readers. Articles of a mathematical nature have been the most controversial ones. They have been enthusiastically received by many readers, and loudly criticized by others. Frankly, we attempt to devote a reasonable amount of space to presentations sufficiently advanced that only 10% of our readers will find this material easily digestible. The balance of the material in each issue is selected to serve the other varied interests of our diversified profession. We have avoided duplication of coverage available elsewhere in order to provide a unique service to you. We feel that the JOURNAL should help in the growth and development of the profession of Industrial Engineering and of the membership of AIIE.

Now we have briefly outlined our efforts to serve—where do we go from here? We would like to mention a few services that you could help provide for yourself. These are along the lines of helping us do a better job for you. First, let us know your reactions. Second, participate—send in comments and discussion. Third, write or encourage your associates to submit material that you think should be published. Fourth, encourage subscriptions by your company and by individual acquaintances. Fifth, help secure advertising.

It's your Journal—help us make it what you want.

R. N. LEHRER

# Better Management = Management + Industrial Engineering + Linear Programming

**By John J. Wilkinson**

*Methods Engineering Council, Pittsburgh, Pennsylvania*

After many years of searching, equations for better management have been found! This search revealed new, *practical uses* of equations—linear equations and *Linear Programming*.

There are two basic directions in which Linear Programming will help the Industrial Engineer:

(a) Your industrial engineering work will be made less difficult, and the results more accurate and specific, by the application of Linear Programming to calculate the over-all results for such problems as:
1. Manufacturing programming.
2. Machine loading.
3. Assembly line programming.
4. Effect of methods improvements.
5. Effect of requirement changes.
6. Effect of breakdown emergencies.
7. Manufacturing locations.
8. Minimizing over-all costs.
9. Effect of new equipment.
10. Product mix alternatives.
11. Make or purchase options.
12. Cost comparisons.

(b) A thorough working knowledge and application experience of Linear Programming will prepare you more quickly for promotion in the higher management field. The reason—you will be equipped to make better management decisions more rapidly; your value and prestige in the company, and in industry, will be increased.

Linear Programming is a new tool—a new tool so powerful, so heavy with potential uses, that some people may believe it is a panacea—a universal remedy for management ills. However hopeful we may be, this is obviously not the case—but practical application has proved conclusively that it will lead the way to better decisions. Linear Programming will reduce the need for "guesstimates," precedents, and relying on past experience, by presenting clearly defined programs and results which are the best of many possible choices and alternatives.

Your fact-finding, accounting, measuring, and forecasting methods and equipment have already been improved to such an extent that you tend to become overwhelmed. Swamped with facts and alternatives. Now you have available a new tool—Linear Programming—which in many cases will help *you* make the best decision; or enable you to pass on facts regarding costs and alternatives which clearly show the most profitable, or least penalty, decision to be made.

Yes, this information will indicate the best decision—also the alternatives—and facilitate recalculation in the light of changes, failures, and unexpected emergencies. It shows how much a certain course of action will cost—the greatest profit under the most favorable circumstances, and the least penalty under the most unfavorable.

Truly, the "Equations for Better Management" have been found. Linear Programming will contribute to better results through better management for at least two reasons:

1. The new and more powerful techniques are making possible more effective management of a firm's resources including people, money, machines, material, and time.
2. The ability of the executive and manager will be improved because these techniques have the effect of increasing the understanding of problems and providing a better way of solving them.

These two factors—more powerful tools of analysis and broader, more effective insight into the cause and effect of relationship problems—promise to open up an entirely new way of approaching, thinking about, and solving the problems that beset all levels in an organization.

We shall see that linear equations and inequations are used, but the procedure is simple and straightforward for the right type of problem.

An *equation* may state that: $100 = A + B$ or Better Management = Management + Linear Programming. *Inequations* would show: $100 + 10A + C > P + Q$ or Manager + Industrial Engineer + Linear Programming > Manager + Industrial Engineer. (These inequations state that the Left Hand Side is "greater than" the Right Hand Side. Combined with an equality sign the inequation becomes $100 \geq (A + B)$—which means 100 is "greater than or equal to" $(A + B)$). A knowledge of high school mathematics and these inequations will enable anyone to apply Linear Programming procedures when the information is tabulated or set into a matrix.

### What is Linear Programming?

We have said that it is not a panacea. However, it *is* a remarkably useful tool—a procedure at present being used, and which will be much more widely used in the future. Linear Programming, to the management man, is a method of calculating the best answer(s) to a problem or situation in which many solutions are possible because of the many variables, limitations, and conditions involved.

In short, it is a method of calculating the best choice where various choices exist. This is one of many similar definitions of Linear Programming—the one we, as practical men, will prefer. However, a mathematician will say that Linear Programming is "a method of maximizing or minimizing a linear function subject to linear restrictions." The economist will say it is "a method of allocating a group of limited resources among a number of competing demands where all decisions are interlocking because they are made under a common set of fixed limits."

Essentially, these three definitions have the same meaning. Whichever one we choose is immaterial. We now need to gain an understanding of the methods used, how *you* can use them, how the techniques are applied in industry today, and how they may be applied tomorrow. Linear Programming has so far only scratched the surface of a large area of usefulness. Daily, further progress is being made both with procedures and application. We will discuss more of this later.

Many decisions are made without fully knowing the facts, the alternatives, the advantages foregone, and profits lost. To overcome these weaknesses we can take a logical, orderly approach:

1. *Organize* the facts and information about a problem—especially the actual objective desired. Frequently we find ourselves trying to solve a problem about which we do not have adequate information—and more surprising, but nevertheless frequently the truth, not knowing what we actually want to find.
2. *Analyze* all possible alternative solutions to the problem. A statement easy to make, but so very difficult to carry out if many alternatives and restrictions must be considered.
3. *Select* the best course to follow under specified conditions. This selection is easy *if* we have all the alternatives, and all possible answers neatly calculated and compared for us.
4. *Plan* the specific steps required to get the best results. In other words, apply the information you have obtained.
5. *Re-evaluate* the plan when conditions change. This may mean a complete re-calculation involving as much work as the original plan, if we do not have some procedure to reduce this re-calculation time.

You will agree these five steps would give a realistic approach to a problem—but can you carry out each one? Does it involve weeks of work? Or are there so many facts, figures, and alternatives that the human mind cannot possibly consider them all simultaneously? Have these procedures and steps ever been formalized even for your problems which repeatedly have to be solved?

Linear Programming will follow these steps; will formalize the procedure; will enable you to get a solution; guide you to a better solution; and tell you when the best has been reached. Then it will enable you rapidly to consider alternatives, and re-evaluate for changed conditions.

Linear Programming is a special way of handling information mathematically.

By going through a finite number of mathematical steps we can arrive at the answer being sought. But, as we will see later, information must be recorded in a very particular manner, and is then treated according to specific rules. When the best answer is found, the solution tells you it is the best, and it can be checked accurately to be sure that it is correct.

Linear Programming comes under the general heading of Operations Research—along with Statistical Mathematics, Probability Theory, Stochastic Processes, Queues and Waiting Lines, the Monte Carlo Method, Game Theory, Search Theory, and Symbolic Logic. But Linear Programming is rapidly becoming the most widely used of these techniques, for the solution of practical problems on a practical basis.

**Application of Linear Programming**

The procedure of Linear Programming has been applied under several names in a great variety of situations. There have been applications to war-time problems, government projects, cattle feeding, vegetable growing and processing, which may not directly interest us. However, in addition to the twelve Industrial Engineering problems already listed, the following seven fields may remind you of some of your management problems to which Linear Programming can be applied:

1. Balancing storage and production facilities.
2. Minimizing transportation costs among warehouses and outlets.
3. Exploring alternative plant or warehouse locations.
4. Exploring the effect of pricing and price changes.
5. Evaluating sales programs.
6. Establishing most equitable salary classifications.
7. Determining the best inventory strategies.

Many cases could have been quoted, but three may typify the results:

1. *Production Planning and Machine Assignment*—In one plant, savings in machine hours are yielding an increase in output of 15%. Overtime hours were eliminated, and the number of people required for a given level of production was reduced. Similarly, in another plant the savings in machine hours for the first four months amounted to $34,000. Again, overtime was eliminated, setup time was reduced, and a number of operating personnel were made available for work in other parts of the plant.
2. *Leveling Production Load Variations*—A plant machining and assembling expensive components had a marked seasonal fluctuation in work load, which previously necessitated varying the number of skilled employees. Certain items had to be purchased, others could be purchased if desired. Some finished components could be stored easily at low cost, others could not. The problem was to develop an over-all plan of make or purchase, or make ahead and carry inventory, which would level production over the whole year at minimum cost to management. Linear Programming gave the over-all plan, with built-in alternates, and a rapid method of recalculation if any changes in sales forecast or the like occurred. The minimum cost—or least penalty—was accurately calculated. This was a small fraction of the cost estimated in the conventional manner.
3. *Determining what to make or buy*—A company manufacturing a line of special handware was able to sell more than it could produce. The policy laid down by management was to supply nearby markets first, then ship to areas in ever-wider circles until production was used up. Distant markets were supplied by outside purchases for resale. Linear Programming showed that for some prod-

uct mixes it was more profitable to manufacture certain products and absorb the distribution costs to distant points rather than purchase for resale. Facts were given to enable management to decide which items to purchase, and which to produce to obtain maximum profit.

These are only examples—areas in which Linear Programming has been used recently. The extent to which Linear Programming can be useful and the areas to which it can be applied are limited only by the resourcefulness and ingenuity of those who use the information and set up the problems. The application of the techniques, rather than the mechanics of the solutions, will be the most fertile fields for future progress.

### What You Need to Know About the Problem

In order to apply any one of the Linear Programming techniques we need to know:

1. *The objective desired*—we must be able to express what is desired in mathematical terms. It may be to minimize costs, maximize profits, obtain the least penalty, compare alternate course of action, or the like. But we must be able to express it mathematically! How frequently we fail to solve a "problem" because we have never factually stated either in words or symbols what we really want to achieve. We actually try to plan the play before we decide whether we want to win, tie, or lose the ball game!
2. *The restrictions and limiting conditions*—These locate the bounds beyond which we must not step on our way to accomplishing the objective. These restrictions and limitations may be capacities, requirements, time, sales limitations, or even whimsies of the boss. If it is the latter, we can point out the effect it has—facts and figures may change such things much faster and more diplomatically than mere words. The Linear Programming solution will enable us to re-evaluate in the light of changes in conditions and limitations. These may be changing monthly or weekly figures, or estimates which have to be revised when further information is available.
3. *Other relevant facts expressed numerically*—We need related information of costs, selling prices, penalties, profits, and capacities, expressed numerically. If we cannot express such intangibles as customer service, good will, or similar numerically, we can estimate and re-evaluate later. Or Linear Programming solutions can be obtained and compared to see what these intangibles are actually costing in loss of profits, failure to meet delivery dates, and so on.

The word "linear" is used repeatedly—even the title *Linear* Programming reminds us of this. We have said that problem information must be expressed mathematically, or numerically—we must also express a *linear* relationship in all cases. The variables must be in the form of linear or first-degree equations—that is, equations which can be drawn as straight lines. We must be able to say that:

$$200{,}000 = 3A + 4B + 2C$$

Perhaps 200,000 is the output capacity in gallons, 3 is the number of hours spent producing at A gallons per hour, 4 is the number of hours at B gallons per hour, and 2 is the number of hours at C gallons per hour.

The situation may not involve truly linear relationships, but they can be made to approximate linearity without appreciable error by use of simple devices. The relationship may be expressed by two or three linked straight lines with different slopes. A line of "least squares" may be plotted for a series of points on a graph, and the assumption made that all points fall on this straight line without appreciable error.

Other similar devices may be used—and if a quadratic relationship ever becomes *essential* we may have practical use for Quadratic Programming.

### How the Problem Information is Organized

There are several methods used in Linear Programming, but each follows the orderly procedure:

1. Stating a problem precisely, where a number of solutions are possible.
2. Establishing a first solution and program which satisfies the conditions of the problem. (This first solution may be reasonably good, and realistic, or it may not be; i.e., it could say, "Don't produce anything, making no profit and no loss"—this could satisfy the conditions!)
3. Computing a series of better solutions until a best solution is obtained. This best solution may be one of several equal best solutions—but there will not be one better. The method will tell you when this best solution has been reached, and what are the alternate best solutions.

The type of problem and the circumstances will indicate the method most suitable, and we will briefly cover each of five basic methods in use today. The MODI, or modified Distribution Method, is most simple to use, and although it involves additional difficulty when "setting up" the problem, it is the most frequently used method. As each of the five methods was developed for particular reasons, and specific applications, we anticipate additional methods of Linear Programming will be added as they are required.

### Linear Programming Methods

#### 1. *The Simplex Method*

The Simplex Method is one of the original techniques developed by the mathematicians. It is the "grandfather" of the other methods, and it is certainly the most comprehensive of them all.

This method sets into a matrix a series of rows made up of algebraic equations and inequations derived from:

1. Capacities.
2. Requirements.
3. Limitations.
4. Yields.
5. Inter-relations.
6. The relative "values" of the variables—frequently in dollars or time.

By the use of various mathematical steps, a series of solutions or programs are calculated until a best program is obtained.

A typical Simplex matrix ready for solution is shown in Figure 1.

| C | | 0 | 0 | 0 | 0 | 3 | 8 | 4 | ← Profits |
|---|---|---|---|---|---|---|---|---|---|
| | | A | $W_1$ | $W_2$ | $W_3$ | X | Y | Z | |
| 0 | $W_1$ | 420 | 1 | 0 | 0 | 6 | 2 | 3 | ← 3 Equations |
| 0 | $W_2$ | 420 | 0 | 1 | 0 | 2 | 3 | 0 | |
| 0 | $W_3$ | 200 | 0 | 0 | 1 | 5 | 0 | 5 | |
| | | 0 | 0 | 0 | 0 | -3 | -8 | -4 | ← Base Row |

Constant Column — Slack Variables — Variables

FIG. 1. Example of Simplex Matrix

This is simplified for illustration purposes. Frequently the problem when set up is so large that the solution may take many days of tedious calculation. Even so, this is only a small fraction of the time that might be required for conventional calculation of the best result. In certain cases it may be worth while to set up computing and data processing equipment to calculate the solution. In all cases, a systematic, patient approach is necessary. With practice, this Simplex method is easy to set up and solve. It is flexible, and universal to the extent that almost any inter-related information can be handled in a variety of forms and different related units. Before insertion into the matrix the equations and inequations are rationalized and where necessary idle or slack variables are used to convert inequations into equivalent equations.

The inequation:

$$420 \geq 6X + 2Y + 3Z$$

is converted into an equation by the addition of the unknown constant "$W_1$"—a slack variable, or dummy product. Thus:

$$420 = W_1 + 6X + 2Y + 3Z$$

becomes the equivalent equation used in the Simplex Matrix.

### 2. *The Distribution or Transportation Method*

The need for more simple and quicker ways of calculating answers to industrial problems led to the development of the Distribution or Transportation Method—and later to other methods.

The Distribution Method was developed to meet a specific need—to handle "transportation type" problems. To determine the lowest cost transportation or distribution program for shipping between origins and destinations. It is developed from the Simplex Method, but has certain essential differences and limitations:

1. The first solution has a realistic value instead of zero.
2. No idle or slack time—all expressions are *equations*, not converted from inequations.
3. The number of circled values must add up to, or be greater than, one less than the sum of the rows and columns.

The twin tables or matrices used for the Distribution Method—ready for calculation—are shown in Figure 2.

In this case we want to minimize the total transportation costs—So if we make all individual costs negative we can allow the procedure to *maximize* the total negative costs. In this way the result will be the *least* or minimum transportation cost for the given program. The initial entries for tons dispatched from origins to destinations are made using the Northwest Corner Rule, which we will describe more fully under the Modi Method. The mechanical procedures will enable us to progress from this initial solution to better solutions, and hence to the best solution. This best solution is indicated by the elimination of all negative numbers from the "vacant" squares in the table.

### 3. *The Modi—Modified Distribution—Method*

The Modi method is a further development of linear programming procedures, to enable us to solve many types of problems more quickly and with less complications.

Since we feel this method is preferable in many cases, and because it has been used successfully in many recent applications, we will go into much more detail, and solve a model problem by the Modi method.

The Modi method is a refinement of the Distribution method. They are very similar procedures, and the results or programs are the same in both cases. The advantage of the Modi method is the saving in computing time—several short cuts are used, and the data is put in one table instead of two. This saves time working back and forth between two tables. Minor changes in procedure enable many of the calculations to be carried out by inspection instead of by pencil and paper.

| Origins | Destinations A | B | C | D | E | Tons Available |
|---|---|---|---|---|---|---|
| Pittsburgh | -4 | -1 | -3 | -4 | -4 | 60 |
| Charleston | -2 | -3 | -2 | -2 | -3 | 35 |
| Weirton | -3 | -5 | -2 | -4 | -4 | 40 |
| Tons Required | 22 | 45 | 20 | 18 | 30 | 135 / 135 |

| | A | B | C | D | E | |
|---|---|---|---|---|---|---|
| Pittsburgh | (22) | (38) | | | | 60 |
| Charleston | | (7) | (20) | (8) | | 35 |
| Weirton | | | | (10) | (30) | 40 |
| | 22 | 45 | 20 | 18 | 30 | 135 / 135 |

FIG. 2. The negative values are the distribution costs in dollars per ton. Circled numbers are tons dispatched from origin to destination.

*Requirements for using Modi method*

As in other methods we must know, and state the objective desired, such as least cost or most profit. We must know the requirements and limiting conditions of the problem—also the available resources must equal the amounts which are required. For example, the total tons required must equal the tons available. Where this is not initially the case, simple devices such as dummy products or capacities can be used to create this equality and satisfy the technical requirements of the method.

A most important requirement is that the data and information of the problem to be solved must be expressed numerically in the *same units*.

This is an essential requirement, and in some problems this is the key to the whole application of the Modi method. There was a similar requirement for the Distribution method, and in the example given we saw it was satisfied by expressing customer requirements in tons, amounts available in tons, and costs expressed in dollars per ton. All used the same unit—tons.

Basically only one set of restrictions can be handled at one time; and specific values, not ranges of values must be used. We will see in the example following that this means some restrictions to general application and difficulty setting up the matrix.

*Procedure for solving problems using the Modi method*

Very briefly summarised the steps are:

(a) Express the problem and objective accurately.

(b) Express information and data numerically in the *same units*—arranging in *equation* form where applicable.

(c) Rearrange the data in a matrix or table according to the Northwest Corner Rule.

(d) Make the basic assignment of "circled values" to squares using the Northwest Corner Rule, and satisfying the requirements of the problem. Cost this program as set up—it is a feasible, but not the best solution.

(e) Compute the Row values and Column values starting with zero (0) in the first of the row values (upper left-hand corner).

(f) Evaluate "open" or non-assigned squares to determine if a better assignment can be made.

(g) Transfer an order, or part of an order, to a vacant or open square indicated by step (f).

(h) Compute new Row and Column values.

(i) Test for successive better assignments, using the procedures given in steps (f), (g) and (h) until no further improvement can be made. That is, until the evaluation of the open squares indicates the best solution has been reached.

(j) Cost this best solution—and extract from the matrix exactly what program is indicated, and must be followed, to obtain this greatest profit, least cost or the like.

These steps can be more readily understood if we work through a simple problem using the Modi method, explaining each step as we proceed with the solution.

*Using the Modi method to solve a "least cost" problem*

Several other articles have shown us how to set up Modi problems, and the appearance of the final maximum profit program. A problem where we require to find least production cost and also exercise a purchase-make option to meet sales requirements will be of interest.

This problem is realistic, but very much simplified, to enable us to more clearly understand the procedure.

We have a toy manufacturing plant, with three paint lines, including masking, spray paint booths, and drying ovens. One line is for green, one for red, and one for two-tone paint jobs. The various models, and various colors, cause differences in the operator-hours required in the paint area. For instance the red Plymouth model requires no masking and only one coat of paint—the lowest painting cost model. The two-tone Plymouth and the two-tone Studebaker and Nash cars require a good deal of masking, and at least two painting operations. Therefore these models have appreciably higher painting costs. Similar variations in masking and painting, between models and the type of paint job, cause differences in the number of operators required to produce them.

It would appear that existing capacity will *not* be able to meet sales demand, and that some paint work will have to be subcontracted—that is painting time must be purchased.

The objective of this problem is to calculate a production program which entails *least cost to produce*. Also to find the model(s) and quantity which may need to be purchased to meet sales requirements.

All finished cars sell at the *same price* (50 cents) and any color can be used to supply the sales requirements for a particular make. The Sales Requirements, Capacities and Limitations are given in Tables 1, 2 and 3. Table 3 shows the number of operators required to mask and paint each model from each line, and gives the variation in production cost.

To apply the Modi procedure we require a standard unit —common to all variables and information. In some problems it is necessary to use an index to bring information into line—perhaps standard line hours compared to Line I. In this problem a slightly different approach may be used, since the drying oven bottleneck will enable us to express capacity in number of *cars*—the same units as the Sales requirements. Similarly, knowing the number of operators required for each model for each line, and the outputs we can determine the production cost *per car*—the same units as before.

From Table 2 we can see that:

*Capacity—Line I* = hours/week × utilization × cars/hour
= 80 × .75 × 100
= *6,000 cars/week*

*Capacity—Line II* = 42 × .833 × 100
= *3,500 cars/week*

*Capacity—Line III* = 42 × .95 × 100
= *4,000 cars/week*

These utilization figures allow for downtime—late starts, early stops, setups, breakdown, minor errors, repairs, and the like.

TABLE 1

*Sales Requirements—Cars to Be Delivered Each Week*

| Plymouth | Chevrolet | Studebaker | Ford | Nash |
|---|---|---|---|---|
| 4,500 | 2,200 | 1,800 | 2,000 | 5,000 |

TABLE 2

*Line Capacities, Utilization and Production Rates*

| | Line I (Red) | Line II (Green) | Line III (Two-tone) |
|---|---|---|---|
| Available hours per week | 80 (2 shifts) | 42 | 42 |
| Utilization per cent | 75.0% | 83.3% | 95.0% |
| Maximum output—cars per hour—from drying ovens | 100 | 100 | 100 |

TABLE 3

*Operators Required to Mask and Paint*

| | Plymouth | Chevrolet | Studebaker | Ford | Nash |
|---|---|---|---|---|---|
| Line I—Red | 1 | 4 | 4 | 3 | 4 |
| Line II—Green | 3 | 2 | 2 | 2 | 3 |
| Line III—Two-tone | 5 | 3 | 4 | 2 | 4 |

The number of operators on the line—masking and painting—can be varied to meet requirements, but the bottleneck of 100 cars per hour from the drying ovens cannot be increased.

TABLE 4

*Cost to Mask and Paint—Cents per Car*

| | Plymouth | Chevrolet | Studebaker | Ford | Nash |
|---|---|---|---|---|---|
| Line I—Red | 1 | 4 | 4 | 3 | 4 |
| Line II—Green | 3 | 2 | 2 | 2 | 3 |
| Line III—Two-tone | 5 | 3 | 4 | 2 | 4 |
| Purchased—Any color | 6 | 6 | 6 | 6 | 6 |

Masking and painting operators paid $1.00 per hour average. Purchased paint jobs—all colors, all models = 6 cents each.

The total capacity is then 13,500 cars per week, and sales requirements add up to 15,000 per week. This means that to get balance in the Modi matrix we must include 2,000 cars per week purchased at 6 cents each.

From Table 3 we can develop the actual cost for masking and painting each car as shown in Table 4. Each operator earns an average of $1.00 per hour—so for each line producing 100 units per hour, each operator will add 1 cent to the cost of masking and painting a car. That is the cost in cents for these operations is equal to the number of operators required. This develops Table 4.

### *The Northwest Corner Rule*

We can now set up the Modi Matrix—but we need to use the Northwest Corner Rule. This rule is not essential to the solution—in fact it sometimes happens that allocating orders by logic for the first matrix will reduce the number of steps in the solution. But we would recommend use of this Northwest Corner Rule, since it is frequently the best and shortest approach. Also it sets out a routine procedure which can be applied by a clerk, and which will always lead to the best answer.

Briefly, the northwest corner rule tells us to set up the framework of the Matrix in a certain way, and then "load" the matrix for a first solution in a certain way.

The Matrix is set up so that, as far as possible the most advantageous "square" is in the Northwest or top left hand side corner. Since rows and columns are integral units, this involves locating the most advantageous (in this case the lowest cost) *column* at the left hand side, and the most advantageous *row* at the top. Then rows and columns next most advantageous are located adjacent to these, until all are located. This means that now the *least* advantageous rows and columns will be at the bottom and the right hand side respectively. For our problem, we total all the rows and columns and locate them in descending order from top to bottom and from left to right in this manner:

Ford (13) Cheve. (15) Plym. (15) Stude. (16) Nash (17)

Line II (12)
Line I (16)
Line III (18)
Purchased (30)

(Totals of costs for rows and columns are shown in parentheses)

The location of rows and columns in this sequence in the matrix follows the Northwest Corner Rule.

If we use the same rule for "loading" the squares, we have a "first solution" which is biased toward the best solution. This is because the least cost squares are in the northwest corner and we start allocating orders into these same squares.

This allocating of orders, or loading the squares, should follow the Northwest Corner Rule in this way:

1. Start in the square in the northwest corner and compare the amount available (capacity) in a row with the amount required by the column.

2. Place the smaller of these two values in the square. If the value fills the sales requirements, move to a square in the same row, but in the next column to the right. If the value does not fill the requirements, move to a square in the same column but one row lower down.

3. Again compare the requirements with the amount available and select the smaller of the two. If the smaller amount represents the remainder available in a row, that value is entered in the square and the remainder of the column requirement is obtained by dropping down to a square in the next row.

4. Repeat the procedure of Steps 2 and 3, exhausting the amount available in each row before moving vertically downwards to the next row; also satisfying the column requirements before moving horizontally to the right to the next column.

### *The first Modi matrix—first solution*

If we can re-arrange rows and columns as described, we can make up the framework as shown in Table 5. The cost values are inserted in small squares within each of

the main squares. These small squares are known as sub-squares and the values within them as sub-square values. In this problem, we desire to solve for *least* cost—that is, we want to minimize the cost of the program. However, the Modi procedure is set up to maximize a function—so if we make all these cost values negative, the procedure will find the algebraic maximum of the negative numbers. In other words, the procedure will find the *minimum* of the positive numbers representing cost of production. This is what we require.

Perhaps we can illustrate the reversal of signs, minimum and maximum, in this way:

$(8 + 4)$ is greater than $(7 + 3)$

*But* $(-8 - 4)$ is less than $(-7 - 3)$ since $-12$ is algebraically less than $-10$.

In our problem, using negative numbers, the maximum we calculate algebraically will be the minimum numerically. This is what the problem requires. This can be shown graphically in Figure 3.

We will use negative numbers in the sub-squares, and the procedure will find the algebraic maximum, which is numerically the minimum. When at the end we remove the minus signs, we get the minimum, or least cost to produce the requirements.

This framework for the Modi matrix, and the negative sub-squares are shown in Table 5.

Using this *one* framework and a pencil and eraser we can completely solve the problem. Each of the steps can be filled in, checked, erased, and revised as required until the final solution has been obtained and checked. However, for clarity in explaining the procedure, we will show several of these erased steps or solutions on separate tables. This would *not* be done when solving an actual problem.

The actual "loading" of "vacant" squares proceeds in this manner. Starting in the northwest corner, the amount available (Line II) is 3,500, and the number of Ford cars required is 2,000, so enter 2,000 in this first square. This says that the 2,000 order for Ford cars will be wholly met from Line II (green). This first sales requirement is met, so we move to the next. This is for 2,200 Chevrolet cars. But we only have 3,500 minus 2,000 capacity remaining on Line II, so 1,500 must be entered in this second square, and 700 in the square below in the same column. This says that the 2,200 order for Chevrolet cars will be met by 1,500 from Line II (green) and 700 from Line I (red). This second sales requirement has been met, so we move to the next. This is for 4,500 Plymouth cars. Now Line I has 6,000 minus 700 capacity remaining, so all the Plymouth sales requirements of 4,500 and 800 of the Studebaker requirements can be met from Line I (red). Proceeding, we supply the remaining 1,000 of Studebaker requirements from Line III (two-tone), and 3,000 of Nash requirements from the same line, utilizing completely the 4,000 capacity of Line III.

This utilizes *all* the capacity from the three production lines, but only 3,000 out of the required 5,000 Nash cars have been supplied. The remaining 2,000 must either be "failure to meet requirements," or if a profit can be made, we must purchase a paint job for 2,000 Nash cars. Each of these values filled in are "circled"—they become known as "circled values"—and are shown in Table 6—the first Modi Matrix.

TABLE 5

*Modi Matrix Framework*

| | | Ford | Chev. | Plym | Stude. | Nash | |
|---|---|---|---|---|---|---|---|
| | $u_i$ Row | | | | | | Capacity |
| Line II Green | | -2 | -2 | -3 | -2 | -3 | 3,500 |
| Line I Red | | -3 | -4 | -1 | -4 | -4 | 6,000 |
| Line III Two-tone | | -2 | -3 | -5 | -4 | -4 | 4,000 |
| Purchased | | -6 | -6 | -6 | -6 | -6 | 2,000 |
| Sales Requirements | | 2,000 | 2,200 | 4,500 | 1,800 | 5,000 | 15,500 |

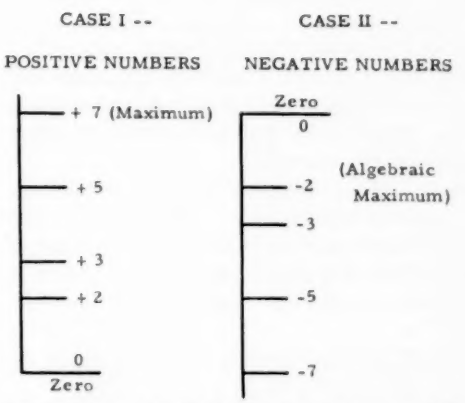



FIG. 3. Note that $-2$ is the algebraic maximum, and also the *numerical* minimum.

TABLE 6

*First Modi Matrix*

| | | Ford | Chev. | Plym | Stude. | Nash | |
|---|---|---|---|---|---|---|---|
| | $u_i$ Row | -2 | -2 | +1 | -2 | -2 | Capacity |
| Line II Green | 0 | -2 (2,000) | -2 (1,500) | -3 +1 | -2 -2 | -3 -2 | 3,500 |
| Line I Red | -2 | X -3 -4 | -4 (700) | -1 (4,500) | -4 (800) | -4 -4 | 6,000 |
| Line III Two-tone | -2 | -2 -4 | -3 -4 | -5 -1 | -4 (1,000) | -4 (3,000) | 4,000 |
| Purchased | -4 | -6 -6 | -6 -6 | -6 -3 | -6 -6 | -6 (2,000) | 2,000 |
| Sales Requirements | | 2,000 | 2,200 | 4,500 | 1,800 | 5,000 | 15,500 |

Cost of program and allocation of orders:

| | | |
|---|---|---|
| Line II (green) | —2,000 Ford at 2 cents | = $40 |
| | —1,500 Chevrolet at 2 cents | = 30 |
| Line I (red) | — 700 Chevrolet at 4 cents | = 28 |
| | —4,500 Plymouth at 1 cent | = 45 |
| | — 800 Studebaker at 4 cents | = 32 |
| Line III (two-tone) | —1,000 Studebaker at 4 cents | = 40 |
| | —3,000 Nash at 4 cents | = 120 |
| Purchased | —2,000 Nash at 6 cents | = 120 |
| Total Cost | | $455 |

This is really *one* solution to the problem. It is summarized, and the cost of producing calculated, below the table, and shows $455 total cost.

Certainly this is one program, and it looks reasonably good, because orders were allocated as far as possible to the lowest cost area by means of the Northwest Corner Rule. But we want to know if it is possible to plan a *better* program with lower cost to produce. Then we want to know what to change to make this improvement, what the better program is, and how much lower cost is involved.

### *Computing better solutions—Row and Column values*

To check this first solution and to indicate any better solution, we next calculate Row and Column values as designated in the matrix. We again start in the northwest corner and arbitrarily assign a value of zero (0) to the top Row Value for Line II (green). Any value could have been assigned here, since we are only interested in comparisons or differences between values. This zero value will make calculation easier.

Now the other Row and Column values are calculated, using only the sub-square values in squares where an order has been assigned (circled values). The process is to calculate Row and Column values which add up to the sub-square value in each case. A formula would show this as:

Sub-square value = Row value + Column value

Calculating some of these Row and Column values for our problem: We have zero in the first row value; the first column value added to this must equal (−2) the sub-square value in the corresponding square which contains a circled value. Similarly, the second column value added to the zero must equal (−2) in the sub-square with a circled value. So the first and second column values are (−2). Using the zero row value, we are unable to evaluate any more column values because there are no further circled values in this row. However, we have a circled value (700) in the second column which can be used to evaluate the second row value by using the (−2) column value, and the (−4) sub-square value. This makes the second row value (−2), which can now be used with the 4500 and 800 circled values to calculate (+1) and (−2) for the third and fourth column values. Similarly, using the circled value sub-square as the link, all the other row and column values can be calculated—as shown in Table 6. We see that:

Sub-square (−6) = fifth column value (−2) + fourth row value (−4)

which agrees with the "formula" already given.

### *Computing better solutions—evaluating "vacant" squares*

We must now evaluate the "vacant" squares—where no "circled values" are assigned—and find where a better assignment can be made. This is accomplished by using the row and column values to evaluate the vacant squares and comparing these with the corresponding sub-square values. If the sum of the row and column values is algebraically *greater* than the sub-square value it signifies that the greatest advantage is obtained by *leaving that square vacant*. On the other hand, if the sum of the row and column values for a certain square is algebraically *less* than the sub-square value, it means that *further improvement can be obtained* by transferring an order to this vacant square. Assigning an order, or part of an order, to this square will take advantage of the *higher value* in the sub-square. In our case, this "higher value" in the sub-square is an algebraically higher number, and the actual result is that we take advantage of a *lower* production cost shown in the sub-square

One technique dictates that *all* the vacant squares should be evaluated in this way, and the square with the greatest potential improvement chosen (that is, choose the square with the greatest difference between the sub-square value, and the *lower* evaluation in the square). On large matrices, experience has shown that a different technique will be beneficial and time-saving—to evaluate vacant squares starting from the northwest corner and stopping at the *first square* with a lower row and column total. Frequently this is the square with the greatest potential, but in any case, the time saved by *not* evaluating all the other vacant squares will, over several problems, offset the occasional necessity of extra matrix steps or iterations.

We will now use the latter technique to choose a vacant square, and re-assign circled values in the Modi matrix.

The row and column values, and the evaluations of *each* vacant square are shown in Table 6 to more clearly describe the technique. In practice, we would only evaluate the Ford—Line I square—to give (−2) + (−2) = −4, which is *smaller* than the (−3) in the sub-square. This is the square chosen for re-assigning a circled value or sales requirement. The other squares are evaluated as shown in these further examples.

Plymouth—Line II = 0 + 1 = +1—greater than (−3) in sub-square

Ford—Line III = (−2) + (−2) = −4—*less than (−2) in sub-square*

Studebaker—Line II = 0 + (−2) = −2—equal to (−2) in sub-square

Chevrolet—Line III = (−2) + (−2) = −4—*less than (−3) in sub-square*

Ford—Purchased = (−4) + (−2) = −6—equal to (−6) in sub-square

*Computing better solutions—improve the first program*

Having chosen the vacant square to work on, we want to improve the program by transferring an order, or part of an order, into this square. This requires a specific procedure.

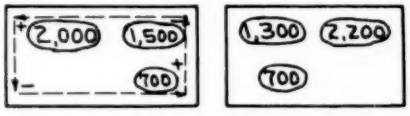
This procedure consists of a series of horizontal and vertical moves—the same as used in the Distribution or Transportation method, and similar to moves in the Simplex procedure. We start with the square to be filled in—into which we desire to assign an order—and move *horizontally* to a circled value which will permit a *vertical* move to be made to another circled value. Then after alternating *horizontal* and *vertical* moves, return horizontally to the column in which the starting square is located. The fewest possible moves should be made—the minimum is four, the maximum is any *even* number of moves—and all moves must be made from a circled value onto a circled value, or the starting square.

In the First Modi Matrix we desire to fill in the Line I Red Ford square. From here we make this series of moves shown by the dotted lines in Table 6:

Horizontally to the right to square, Line I—Red Chevrolet:
vertically upwards to square, Line II—Green Chevrolet:
horizontally to the left to square, Line II—Green Ford:
vertically return to starting square, Line I—Red Ford.

These moves are shown by arrows on the matrix, and then alternating plus and minus signs are assigned to the *corner* squares of the route traced out. We start with a negative sign in the starting square, assign a *plus* sign to the first circled corner square (700), a *negative* sign (1500) and a *plus* sign (2000) to the others, returning to the negative in the starting square. These are also shown on Table 6. We then select the *smallest* assignment or circled value to which a plus sign was given—in this case *700*.[1]

This selected value is *added* to each square having a *minus* sign—including the selected starting square. The selected value is *subtracted* from each square having a *plus* sign. The changes due to the adding and subtracting are shown below.




[1] Italicized numbers in text correspond to circled numbers in tables and figures.

TABLE 7
*Second Modi Matrix*

| | Sq. Row | Ford −2 | Chev. −2 | Plym 0 | Stude −3 | Nash −3 | Capacity |
|---|---|---|---|---|---|---|---|
| Line II Green | 0 | −2 (1,300) | −2 (2,200) | −3 0 | −2 | −3 | 3,500 |
| Line I Red | −1 | −3 (700) | −4 −3 | −1 (4,500) | −4 (800) | −4 | 6,000 |
| Line III Two-tone | −1 | X −2 −3 | −3 | −5 | −4 (1,000) | −4 (3,000) | 4,000 |
| Purchased | −3 | −6 | −6 | −6 | −6 | −6 (2,000) | 2,000 |
| Sales Requirements | | 2,000 | 2,200 | 4,500 | 1,800 | 5,000 | 15,500 |

| Line II | Line I | Line III | Purchased |
|---|---|---|---|
| 1300 x 2 = $26 | 700 x 3 = $21 | 1000 x 4 = $ 40 | 2000 x 6 = $120 |
| 2200 x 2 = $44 | 4500 x 1 = $45 | 3000 x 4 = $120 | |
| $70 | 800 x 4 = $32 | $160 | TOTAL = $448 |
| | $98 | | |

Logically, this means that we move the *700* value into the chosen square, and adjust the other "route" values by this amount to rebalance the row and column totals. We take *700* from the Chevrolet column, so must add *700* in the row above to retain the column total balance of 2200. We have added *700* to the Line II, so must subtract *700* from the next column to retain the row total balance of 3500. This we have done—we have "horse-traded" *700* at a +1 gain (from −4 to −3 sub-square value) for *700* at a zero loss (from −2 to −2 sub-square value), thus reducing the total program cost by $7, and taking one step nearer the optimum solution.

In our case, Table 7—the Second Modi Matrix—is made up exactly the same as Table 6 apart from the four squares revised as above, and the row and column values left blank. In an actual Modi solution, these four square changes would be made by eraser and pencil, and the row and column values erased ready for re-evaluation, *on the original matrix*.

Below Table 7 is an abbreviated calculation of this second program—showing a total cost of $448—a saving of $7 on the $455 cost of the first program.

*Computing better solutions—Improve succeeding programs*

This second program is "improved" in the same way as before—by calculating new row and column values, evaluating vacant squares, choosing a square for re-assigning an order, and then moving the circled or assigned values to suit.

Briefly, the row and column values are calculated (sum = sub-square value for circled value squares only) and the vacant squares evaluated as far as the starting square—Line III—Two-tone Ford which has a −3 in the square and a −2 in the sub-square. The horizontal and vertical moves in this case transfer *700* into the starting square, subtract *700* from the *1000*, add *700* onto the *800*, and subtract *700* from the *700* leaving this square vacant.

TABLE 8

*Third Modi Matrix*

| | For Row | Ford | Chev. | Plym | Stude. | Nash | Capacity |
|---|---|---|---|---|---|---|---|
| | | -2 | -2 | -1 | -4 | -4 | |
| Line II Green | 0 | -2 (1,300) | -2 (2,200) | -3 -1 | -2 -4 X | -3 | 3,500 |
| Line I Red | 0 | -3 -2 | -4 -2 | -1 (4,500) | -4 (1,500) | -4 | 6,000 |
| Line III Two-tone | 0 | -2 (700) | -3 -2 | -5 | -4 (300) + | -4 (3,000) | 4,000 |
| Purchased | -2 | -6 -4 | -6 | -6 | -6 | -6 (2,000) | 2,000 |
| Sales Requirements | | 2,000 | 2,200 | 4,500 | 1,800 | 5,000 | 15,500 |

Line II: 1500 x 2 = $26; 2200 x 2 = $44; $70

Line I: 4500 x 1 = $45; 1500 x 4 = $60; $105

Line III: 700 x 2 = $ 14; 300 x 4 = $ 12; 3000 x 4 = $120; $146

Purchased: 2000 x 6 = $120

TOTAL = $441

TABLE 9

*Seventh Modi Matrix—Final*

| | For Row | Ford | Chev. | Plym | Stude. | Nash | Capacity |
|---|---|---|---|---|---|---|---|
| | | -1 | -2 | 0 | -2 | -3 | |
| Line II Green | 0 | -2 -1 | -2 (1,700) + | -3 0 | -2 (1,800) | X -3 a | 3,500 |
| Line I Red | -1 | -3 -2 | -4 -3 | -1 (4,500) | -4 -3 | -4 (1,500) | 6,000 |
| Line III Two-tone | -1 | -2 (2,000) | -3 (500) - | -5 -1 | -4 -3 | -4 (1,500) + | 4,000 |
| Purchased | -3 | -6 -4 | -6 -5 | -6 -3 | -6 -5 | -6 (2,000) | 2,000 |
| Sales Requirements | | 2,000 | 2,200 | 4,500 | 1,800 | 5,000 | 15,500 |

Line II: 1700 x 2 = $34; 1800 x 2 = $36; $70

Line I: 4500 x 1 = $ 45; 1500 x 4 = $ 60; $105

Line III: 2000 x 2 = $ 40; 500 x 3 = $ 15; 1500 x 4 = $ 60; $115

Purchased: 2000 x 6 = $120

TOTAL = $410

TABLE 10

*Eighth Modi Matrix—Final (Alternate)*

| | For Row | Ford | Chev. | Plym | Stude. | Nash | Capacity |
|---|---|---|---|---|---|---|---|
| | | -1 | -2 | 0 | -2 | -3 | |
| Line II Green | 0 | -2 -1 | -2 (200) | -3 0 | -2 (1,800) | -3 (1,500) | 3,500 |
| Line I Red | -1 | -3 -2 | -4 -3 | -1 (4,500) | -4 -3 | -4 (1,500) | 6,000 |
| Line III Two-tone | -1 | -2 (2,000) | -3 (2,000) | -5 -1 | -4 -3 | -4 -4 a | 4,000 |
| Purchased | -3 | -6 -4 | -6 -5 | -6 -3 | -6 -5 | -6 (2,000) | 2,000 |
| Sales Requirements | | 2,000 | 2200 | 4,500 | 1,800 | 5,000 | 15,500 |

Line II: 200 x 2 = $ 4; 1800 x 2 = $36; 1500 x 3 = $45; $85

Line I: 4500 x 1 = $ 45; 1500 x 4 = $ 60; $105

Line III: 2000 x 2 = $ 40; 2000 x 3 = $ 60; $100

Purchased: 2000 x 6 = $120

TOTAL = $410

This gives us the third program—shown in Table 8—and a new calculated cost value of $441. Again an improvement of $7 reduced cost over the preceding program, due to 700 units moving from a −4 to a −2 square reducing cost by $14 and only increasing it by $7, with the other move of 700 units from a −3 to a −4 square.

This procedure is repeated, and further matrices derived until we reach the Seventh Modi Matrix—shown in Table 9. When we evaluate the vacant squares, using the new row and column values for this matrix, we find that in no case is the evaluated square algebraically *less* than the sub-square value. This means that in no case can we obtain a *better* solution by moving a circled or assigned value. *That is, we have reached the best, or least cost program.*

Yes, this is the optimum program—there are *no* programs with *lower* cost, to satisfy all the requirements. There may be one or more "equal best" programs—where some difference in assignment of orders is possible without increasing this lowest cost figure. These true alternate programs will have *equal* lowest cost values. They can be easily recognized in the final solution in this way.

### *Alternate optimum programs*

Where the evaluation of the vacant square is algebraically *greater* than the sub-square, *no* improvement is possible. Where it is *less*, *some* improvement is possible. Where the vacant square value is *equal* to the sub-square, an alternate assignment into this square is possible without any increase or decrease in the program merit with regard to the cost or time in the solution.

In our case, Table 9, the Seventh Modi Matrix, shows a −3 vacant square value and a −3 sub-square value in Line II—Green Nash—marked with an "a". These values are equal, and re-assignment to this square will yield an "equal best" solution. Re-assignment is achieved by treating this vacant square in exactly the same way as before (as though it was a lower value). The *1500* value is moved from Line III to Line II in the Nash column and the *1700* is reduced to *200* in Line II in the Chevrolet column by adding *1500* to the *500* in Line III. This gives the Eighth Modi Matrix shown in Table 10. This is an alternate best program—a fact which is checked in the normal way by comparing evaluated vacant squares with the sub-squares (finding all equal to or greater than). A calculation of the cost for this alternate program shows us that the lowest cost is $410, as before.

Thus for this problem we have two programs, with different assignment of orders, which may be used with confidence as the lowest cost—$410—to meet all requirements.

### *Conclusions from these Final Programs*

The interpretation of the two final programs is shown in Table 11—information which would be handed over to the production control people and used by sales and planning departments.

From this interpretation of results, and from the seventh and eighth matrices—final solutions—we can see that:

a. All sales requirements have been met.
b. Variety of color has resulted.
c. No capacity restrictions have been exceeded.
d. Orders for Ford, Plymouth, and Studebaker are not split—they will be all one color from one production line.
e. Orders for Chevrolet and Nash have been split—they will be in different colors from different production lines.
f. Either program may be used, as preferred by sales or production people, without any difference in production cost. This allows some flexibility in the programming. The effect of other changes can be evaluated easily—see later.
g. The lowest production cost area—Plymouth on Line I-Red (the −1 sub-square)—has logically to be fully loaded for a least cost program. Similarly, the 2000 purchased units should be the units most expensive to produce ourselves—the Nash model. Both of these logical features are apparent in these final programs.
h. Contrary to expectations, certain other requirements are met from other than the lowest cost areas—the procedure will automatically arrange the program for the best *over-all* results—the least *over-all* cost.
j. In this problem—a model problem, simplified for ease of explanation—it is possible that this best program could be planned logically by an experienced man. But he would not be *sure* it was the best program—"bells do not ring" when the best result is achieved, as they do in the Modi procedure. On a large programming solution—a more frequent occurrence—he would not be able to handle it logically.
k. An increase in capacity of any line would save over-all cost by reducing the purchases at 6 cents, but most advantage would be obtained if the 2000 purchases were handled on Line II, the lowest production cost line. (The best for any capacity increase).
l. Certain models on certain production lines would be worthy of concentrated methods improvement effort, to obtain lower cost production. Certain other methods improvements would be of little or no value in lowering costs (large differences between vacant square and sub-square values).

This completes the explanation of the Modi Procedure of Linear Programming.

We have said that the effect of changes in conditions, requirements, capacities, and costs can be rapidly and accurately handled by the Modi Procedure. The following examples are only a few of many possible revisions and changes which could be put into the problem, the best program calculated, and the revised least cost figure compared to assess the value or cost of the change.

*Exploring the effect of methods improvements*

(a) Two-tone Plymouth on Line III

This is the most expensive model to produce, according to records. It requires five operators, and would appear to be an ideal area for methods improvement. Suppose we make a very admirable methods change so that three operators instead of five can mask and paint this model—how does this affect the over-all problem?

The sub-square value becomes −3 instead of −5 cents. Now we can re-program or merely consider the final matrices. The evaluation of this particular open square is not changed, it is −1. This and all previous evaluations are greater than −3, the new sub-square value, and it is never advantageous to assign an order or part of an order to this square. So the optimum solution will not be changed, no two-tone Plymouths will be made, and this methods improvement gives *no* over-all advantage.

TABLE 11
*Interpretation of Two Best Programs*

| Sales Requirements | Line & Color Used | Hours Run | Quantity Produced | Dollar Cost | Program |
|---|---|---|---|---|---|
| 2,000 Ford | II Green | 20 | 2,000 | 40 | Seventh Modi Matrix Program<br>Total Cost = $410 |
| 2,200 Chev. | II Green<br>III Two-Tone | 17<br>5 | 1,700<br>500 | 34<br>15 | |
| 4,500 Plym. | I Red | 45 | 4,500 | 45 | |
| 1,800 Stude. | II Green | 18 | 1,800 | 36 | |
| 5,000 Nash | I Red<br>III Two-Tone<br>Purchased | 15<br>15<br>-- | 1,500<br>1,500<br>2,000 | 60<br>60<br>120 | |

| Sales Requirements | Line & Color Used | Hours Run | Quantity Produced | Dollar Cost | |
|---|---|---|---|---|---|
| 2,000 Ford | III Two-Tone | 20 | 2,000 | 40 | Eighth Modi Matrix Program<br>Total Cost = $410 |
| 2,200 Chev. | II Green<br>III Two-Tone | 2<br>20 | 200<br>2,000 | 4<br>60 | |
| 4,500 Plym. | I Red | 45 | 4,500 | 45 | |
| 1,800 Stude. | II Green | 18 | 1,800 | 36 | |
| 5,000 Nash | II Green<br>I Red<br>Purchased | 15<br>15<br>-- | 1,500<br>1,500<br>2,000 | 45<br>60<br>120 | |

(b) Two-tone Studebaker—Line III

Suppose a similar methods improvement could be made on this model, and the number of operators to mask and paint can be reduced from 4 to 2. Before installation, let us see the over-all effect this has on our program. We see that in the previous optimum programs no orders were assigned to this square.

Now we will reprogram with the particular sub-square value changed from −4 to −2 cents. We may *start* from the optimum Eighth Modi Matrix, and calculate the new optimum program shown in Table 12—a Modi Matrix showing the effect of this methods improvement. The calculated least cost is now $392 per week—a saving of $18 week from the previous program. Using this information, we can rapidly and quantitatively decide whether this methods improvement should or should not be adopted. Knowing the cost of installing the methods change, we can calculate how many weeks, at $18 saving per week, will be required to amortize the installation

cost. An accurate and scientific way of making a decision regarding this change. A decision which has taken into account the over-all, inter-related effect of the change. Using this same procedure, the over-all effect of any methods change which affects production cost can be calculated.

TABLE 12

*Modi Matrix to Show Effect of a Methods Improvement*

| | | Ford | Chev. | Plym | Stude. | Nash | |
|---|---|---|---|---|---|---|---|
| | Eq. Row | -1 | -2 | 0 | -1 | -3 | Capacity |
| Line II Green | 0 | -2 / -1 / 2,000 | -2 | -3 / 0 | -2 / -1 | -3 / 1,500 | 3,500 |
| Line I Red | -1 | -3 / -2 | -4 / -3 | -1 / 4,500 | -4 / -2 | -4 / 1,500 | 6,000 |
| Line III Two-tone | -1 | -2 / 2,000 | -3 / 200 | -5 / -1 | -2 / 1,800 | -4 / -4 3 | 4,000 |
| Purchased | -3 | -6 / -4 | -6 / -5 | -6 / -3 | -6 / -4 | -6 / 2,000 | 2,000 |
| Sales Requirements | | 2,000 | 2,200 | 4,500 | 1,800 | 5,000 | 15,500 |

| Line II | Line I | Line III | Purchased |
|---|---|---|---|
| 2000 x 2 = $ 40 | 4500 x 1 = $ 45 | 2000 x 2 = $ 40 | 2000 x 6 = $120 |
| 1500 x 3 = $ 45 | 1500 x 4 = $ 60 | 200 x 3 = $ 6 | |
| $ 85 | $105 | 1800 x 2 = $ 36 | |
| | | $ 82 | TOTAL = $392 |

TABLE 13

*Modi Matrix with Sales Restrictions on Color*

| | | Ford | Chev. | Plym | Stude. | Nash | |
|---|---|---|---|---|---|---|---|
| | Eq. Row | -2 | -2 | 0 | -2 | -3 | Capacity |
| Line II Green | 0 | -2 / 0 | -2 / 2,200 | -3 / 0 | -2 / 800 | -3 / 500 | 3,500 |
| Line I Red | -1 | -3 / -3 3 | -4 / -3 | -1 / 2,500 | -4 / -3 | -4 / 2,500 | 5,000 |
| Line III Two-tone | 0 | -2 / 2,000 | -3 / -2 | -5 / 0 | -4 / -2 | -4 / -3 | 2,000 |
| Purchased | -3 | -6 / -5 | -6 / -5 | -6 / -3 | -6 / -5 | -6 / 2,000 | 2,000 |
| Sales Requirements | | 2,000 | 2,200 | 2,500 | 800 | 5,000 | 12,500 |

| Line II | Line I | Line III | Purchased |
|---|---|---|---|
| 0 x 2 = $ 0 | *1000 x 4 = $ 40 | *2000 x 5 = $100 | 2000 x 6 = $120 |
| 2200 x 2 = $44 | 2500 x 1 = $ 25 | 2000 x 2 = $ 40 | |
| 800 x 2 = $16 | 2500 x 4 = $100 | $140 | |
| 500 x 3 = $15 | $165 | | TOTAL = $500 |
| $75 | | | |

*Orders pre-assigned.

*Exploring the effect of sales requirement changes*

Two cases are indicated:

(a) Sales department insist on 2,000 Plymouth cars being two-tone, and 1,000 Studebaker cars being red.

Since there is no choice or alternative about these specific requirements, they are taken out of the matrix solution. The sales requirements for Plymouths are reduced from 4,500 to 2,500 and for Studebakers from 1,800 to 800. The capacity of Line III—Two-tone—is reduced from 4,000 to 2,000, and the Line I—Red—from 6,000 to 5,000. With these changes a new program is calculated. This new program is shown in Table 13, and the least cost is now $500. (This solution involves the use of a "dummy.") This means that these specific demands for special colors result in increased costs of $90 per week. (The Red Ford square shows an *alternate* optimum assignment possible.) This may be sufficient to persuade sales department to change their specific requirements in line with one of the two alternate least cost programs shown in the Seventh and Eighth Modi Matrices. At least they can be told what it is costing the organization to meet these demands.

(b) The demand for Studebaker cars drops and it is decided to discontinue this model.

The Modi Matrix is redrawn with one less column, the revised requirements filled in, and a new program calculated. This new program is shown in Table 14, and the least cost is now $320. This program shows one alternate optimum solution (two-tone Chevrolet) and would indicate that appreciable effort (or overtime) would be worth while to obtain a further 200 cars capacity from one of the lines, to eliminate the 200 paint jobs at present purchased.

TABLE 14

*Modi Matrix with Sales Requirement Change*

| | | Ford | Chev. | Plym | Stude. | Nash | |
|---|---|---|---|---|---|---|---|
| | Eq. Row | -1 | -2 | 0 | | -3 | Capacity |
| Line II Green | 0 | -2 / -1 | -2 / 2,200 | -3 / 0 | | -3 / 1,300 | 3,500 |
| Line I Red | -1 | -3 / -2 | -4 / -3 | -1 / 4,500 | | -4 / 1,500 | 6,000 |
| Line III Two-tone | -1 | -2 / 2,000 | -3 / -3 3 | -5 / -1 | | -4 / 2,000 | 4,000 |
| Purchased | -3 | -6 / -4 | -6 / -5 | -6 / -3 | | -6 / 200 | 200 |
| Sales Requirements | | 2,000 | 2,200 | 4,500 | | 5,000 | 13,700 |

| Line II | Line I | Line III | Purchased |
|---|---|---|---|
| 2200 x 2 = $44 | 4500 x 1 = $ 45 | 2000 x 2 = $ 40 | 200 x 6 = $12 |
| 1300 x 3 = $39 | 1500 x 4 = $ 60 | 2000 x 4 = $ 80 | |
| $83 | $105 | $120 | TOTAL = $320 |

### 4. *The Index Method*

For certain types of problems, frequently scheduling and loading of bottleneck areas or machines, a fourth Linear Programming technique—the Index Method—is used. This is usually required after the over-all planning has been carried out—perhaps by the Modi Method—and the detail, shop floor, scheduling must be done in the most efficient way. The Index Method follows strict logic for loading machines, and the like, but utilizes a number, or Index, to guide the steps in the best direction, and to check the result. Following this method, we very quickly obtain a program which is not so precise as the Modi Method, and which may not necessarily be the absolute optimum. (It is usually very close to the optimum, although an extra small improvement can sometimes be effected by spending additional time or using other methods.)

However, what the Index Method loses in preciseness or perfection is offset by a very marked saving in time for solution.

A typical matrix for an Index Method solution is shown in Figure 4.

The index values in the sub-squares indicate the relative inefficiency of the machines. "Ideal" loading or scheduling is into the squares with zero index—shown by numbers within solid circles. This overloads certain of the machines and underloads others. Orders must be re-assigned with least penalty or excess hours. The completed re-assignment is shown in the matrix by crossing out circled values not used, and adding assignments by numbers within the broken circles. This best solution has 75 excess hours, and the largest index square loaded is 0.5. Care must be taken in this method to avoid too many "split" orders, which may generate excessive setup costs.

| | 1 | 2 | 3 | 4 | 5 | Excess |
|---|---|---|---|---|---|---|
| A | 5.0 180 | 0 (30) | 1.0 60 | 2.0 90 | – – | |
| B | – – | – – | – – | 0.75 140 | 0 (80) | |
| C | 0 (80) | 0.5 120 | 2.0 240 | 1.0 160 | 3.5 360 | |
| D | 0 (60) ~~(60)~~ (80) | 1.0 320 | 0.75 280 | 0.5 ~~(40)~~ (120) | 0.6 256 | 40 |
| E | – – | 2.0 600 | 0 (200) | 0.5 300 | 1.0 400 | |
| F | – – | 2.0 210 | 0 ~~(70)~~ | 0.5 105 | 0.5 (105) | 35 |
| Total Available | 160 | 32 | 200 | 160 | 190 | |
| Req'd. | 240 | 30 | 270 | – | 80 | 75 |

Fig. 4. Example of Index Matrix

### 5. *The Ratio Analysis Method*

A completely new method—relatively untried in practical situations. It has promise as a rapid, easy to handle procedure, based on simplified methods of visually and directly comparing profits, requirements, and capacities.

### 6. *Other Linear Programming Methods*

This heading indicates our approach to Linear Programming. It is a new, flexible tool. New methods will be developed as the application requires. These new methods may be complex mathematical procedures, or they may be comparatively simple tabulation procedures. We are still dealing with *linear* relationships—it is still *programming*—it is linear programming.

## Conclusions

In this paper we have discussed the general uses of Linear Programming and have listed many areas of application. The technique has been widely applied to many different practical problems, and has had phenomenal success in finding solutions. Many difficult problems have been solved immediately; some impossible ones have taken a little longer! Management, including Industrial Engineers, have found use for this tool within their organizations. They have called in specialists on a consultant basis, and men have been trained in Linear Programming to enable day-to-day use of this technique. In all cases "Equations for Better Management" have resulted in better decisions, and increase in prestige for the people involved.

The *practical* use of Linear Programming has been stressed, and five methods have been mentioned. One method—the Modi, or Modified Distribution Method—has been described in detail, and a step-by-step calculation of a model problem given to make the procedure more understandable. This Modi method was chosen for detailed consideration because of its neat compact approach to the solution—and the fact that it is more widely used than the other methods where suitable standard units can be found.

We believe this will have shown you that the use of the new tool—Linear Programming—is practical. That the technique will help us all to make factual comparisons of alternatives and hence to make better management decisions.

You will find uses for the Linear Programming techniques, and will gain a new concept of planning and scheduling problems. You will be able to calculate optimum results when required to make a best choice where choices exist.

# An Economist Looks at Automation*

**By Sidney C. Sufrin**

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## I

From the viewpoint of the engineer and possibly of the sociologist and politician, "Automation" has many aspects of novelty. Automation may imply new social habits, new administrative techniques, and new techniques in social organization. To the economist, however, automation means basically technological improvement—the reordering or changed combinations of labor and capital in production. It might very well be that, in recent years, technological improvement has increased in tempo, or made great substitutions of capital for labor, or new forms of specific capital for older forms of specific capital. To the economist, concerned with costs and returns, with employment and unemployment, with capital accumulation and income distribution, with fluctuations in business activity, automation is essentially a problem of capital accumulation directed toward labor saving or capital saving ends, or toward new and cheaper ways of producing goods.

The economic literature concerned with technological development has largely concentrated on the question of *technological unemployment.*

In the 1930's although unemployment was rife, leading technical opinion held that the introduction of a technological device *automatically* implied cost reductions, passed on to the consumer as price reductions, with employment increasing as a result of increased purchases. If costs and prices of any products fell, income, it was argued, was released for other purchases. The result was that the technologically unemployed were automatically reabsorbed into the economic system.

The effect of technology on business decisions, and upon the organization of the firm, was much less discussed than the employment aspects. Indeed, one can scarcely find more than a passing reference to the economics of technological development outside of the labor field. By and large capital theorists have assumed "the coefficients of production" as fixed. Galbraith, in his "American Capitalism" (p. 91) goes so far as to say, "Technical development has long since become the preserve of the scientist and engineer". His point is that industrial progress is a broader phenomenon than merely economic.

In this discussion we shall consider both the labor and business aspects of technological improvement, or, if you will, "Automation".

### The Economics of Technological Unemployment

It should be pointed out that insofar as technological development results in the creation of new products, the problem of technological unemployment recedes in importance. It is one thing to make old products in a new fashion; it is quite another thing to make a brand new product, whether for ultimate consumers or for industry.

For example, the introduction of capital saving and labor saving devices may reduce the cost of manufacturing typewriters. This is accomplished by the reduction of the capital and labor requirement to make a typewriter. Then there arises the question, "Will the released labor and released capital have adverse effects on the labor and capital marked?" or "Will persons who formerly were employed making typewriters find new employment, or will they find employment at very much lower wage rates and in industries to which they are not adapted?" These questions present one type of social problem.

When science and technology develop new methods of communications, such as radio and television, or develop foods, medicines or chemicals undreamed of 50 years ago, or develop Univacs and transistors, questions relating to unemployment are often irrelevant. The likelihood of unemployment being caused by *new* products is obviously less than unemployment caused by new ways for making *old* products. This leads to a proposition which is valid in many social situations.

"Any deleterious and untoward effects of technological advance on employment is dramatically reduced since new products are more likely to create employment than to reduce employment".

## II

Let us pinpoint our interest on the effects of the introduction of labor or capital saving devices to make old products in new ways. By labor saving device we mean a piece of capital which does the job formerly done by labor. A good example would be a steam shovel. Steam shovels move earth just as people move earth. One steam shovel, however, does the work of many hundreds of common laborers, and at a much lower cost. A capital saving device, on the other hand, is one which results in a greater *output* per dollar of investment than with the older piece of capital, or more correctly, capital technique.[1]

* This article is adapted from a chapter in *Labor Problems at Mid-Century* by Sufrin and Sedgwich to be published in 1956 by Knopf Publishing Company.

[1] *Income, Employment and Public Policies—Essays in Honor of Alvin S. Hanson*, Benjamin Higgin, "Concepts and Criteria of Secular Stagnation", p. 101.

If the introduction of labor saving or capital saving devices in a firm appreciably reduces the cost of production, their introduction enhances profits, and may possibly permit a monopoloid, or at least preferred business position, for the firm which is the innovator. Unemployment may then occur in firms formerly selling the same market as the firm with the new technique and preferred position. Some of the unemployment arising from the competitors' failure to hold the market will occur, but an offset will be found either in the increased employment in the firm with the new technique or in the firms making the new capital devices.

If a labor or capital saving device provides a product which is much cheaper than the older product, or much more useful and attractive, then, it is uncertain whether employment will decrease at all. The shift of the demand might offset any employment. Indeed, employment for such a technological monopoloid firm might actually increase to compensate or even overcompensate for the original unemployment. In this case the technological improvement has resulted in essentially a new product.

Where technology results in new products, there is a strong tendency that it increases rather than decreases employment. Machine made shoes surely increased the employment of people engaged in making shoes.

This leads to a second proposition: "The quantity relations between the new employment and the unemployment similarly caused cannot be known except by empirical investigation."

It is important, when considering problems of technological improvement, and the employment and unemployment arising from such improvement, to realize that rarely does a whole economy find itself undergoing great improvement at *precisely the same time*. More realistically, various segments of the economy introduce labor and capital saving devices at different times and different rates, so that industrial development is uneven. The rates of progress in various segments of society are decidedly unequal, so that while one industry is developing at a great rate, other industries are developing not at all, or at slower rates. The very unevenness of this development may cause some frictional unemployment, but it is unlikely to cause great waves of technological unemployment. It should not be forgotten, however, that often a given technical advance makes it possible to use other technical ideas which were developed previously, but were put on the shelf of ideas because they had no current use. This does lead to small waves of development.

## III

As industries develop, and as technological changes occur, some of the unemployed tend to find jobs in other industries. Some find new jobs in their old industries because the technological improvements, if general enough, may cause the old, high cost industries to operate fully because of the prosperity based on successful technological investments. This provides a corollary to our second proposition: "If technological improvement (read new capital formation) increases the size of income flow, it generates employment and prosperity rather than unemployment".

The tendency for employment, leisure and the standard of living to increase together is a characteristic of a progressive economy. In such an economy, some frictional or technological unemployment might and does occur, and some individuals may be unemployed for long periods. To argue, however, that technological improvement *automatically* results in the absorption of the technologically unemployed is improper. To argue that such reabsorption is *necessary* and immediate is to argue that we live in a static economic system which automatically moves toward equilibrium. There is little in logic or historical analysis to support this view. In many parts of the United States there are pockets of structurally unemployed persons. The development of the carpet industry in the South has made wool and carpet industries in parts of New England and New York so unprofitable that the output of the latter is very low. In these towns there are persons who have been unemployed as a result of technological improvements in the South. The unemployed in the North do not immediately, and successfully, seek jobs elsewhere. Many of them are too old to find it easy to move; others are unwilling to work for lower wages than they received as skilled weavers; others are ignorant of job opportunities; while still others find that there simply are no job opportunities which are appealing to them. Such persons in structurally distressed areas may be considered technologically unemployed.

In addition to the social elements which cause labor immobility and therefore make reabsorption of technologically unemployed difficult there is another consideration. With technological change going on at a fairly rapid rate then, one may expect the income distribution of the United States to undergo changes. There is no reason to assume that the average or marginal propensities to consume of all the income classes in the United States is identical, so that the changing size and distribution of the national income will have no effect upon consumption patterns. In point of fact, we can reasonably expect changes in size or distribution of national income to have appreciable effects on the consumption patterns of the various income sectors and geographical areas. Changes in consumption patterns clearly will have their effects upon changes in employment in the consumption industries, and in the industries providing goods and services to the consumption industries. Inductive investigation rather than speculation is necessary to assess the magnitude and nature of the changes.

## IV

The introduction of labor saving devices in industry in the long run *may* result in changes in the wage hierarchy due to shifting of the demand for labor from one class of labor to labor of a lesser skill. In the short run, however, there are resistances to wage decreases, absolute or relative, and to hierarchal shiftings. Such resistances may actually cause unemployment to increase beyond what it

would have were wages and prices cut together. On the whole, as technology increases productivity, it tends to increase real (absolute) wages.

There is some indication that the relations between labor and capital are more likely to be relations of complement rather than substitution. In the short run, or better, in realistic circumstances, the introduction of *new* capital to an industry doesn't displace labor so much as it requires a given complement of labor for each new unit of capital. The result is often to increase output at lower prices, rather than to maintain a constant output at lower prices. In the long run, however, it is fairly clear that capital may be substituted for labor. The whole history of the 20th century bears this out, since fewer workers are employed per unit of capital now than a hundred years ago. This substitution, too, is related to a bigger output per unit of cost or investment; i.e. real costs tend to fall in the long run.

A fourth proposition may be stated as having validity in many circumstances: "In a rapidly changing society such as ours, unemployment (or its converse, employment) in the short run is less likely to be related to wages, than in the longer run. In the long run, factoral substitution, depending on costs and returns, will determine the incidence of the employment of labor and use of machines".

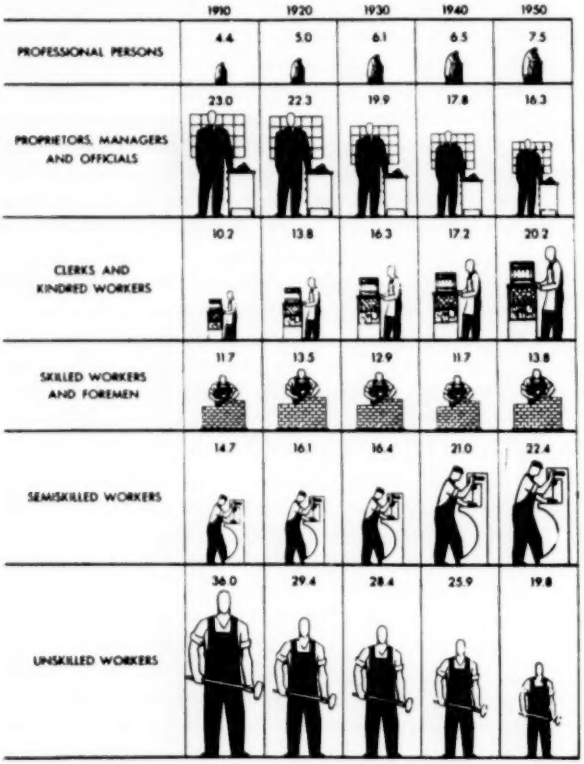


FIG. 1. Changes in Skill Distribution. United States, 1910–1950. The numbers in each vertical column are percentages showing the composition of the labor force in the year indicated. Chart is from *Scientific American* September 1951, based on data of the U. S. Bureau of the Census and U. S. Bureau of Labor Statistics.

## V

Figure 1 and Table 1 show the distribution of the working force of the United States from 1910 to 1950. Excluded are persons working in agriculture and mining.

TABLE 1

*Skill Distribution in the United States*

The average level of skill is higher, in the whole labor force, than early in this century. The percentage of highly skilled and supervisory workers has increased only a little, but the sharp decline in the proportion of unskilled workers has been matched by a sharp rise in semiskilled. Common laborers, of whom there were about 11 million in 1910—half of them in agriculture—numbered less than 6 million by 1950. There has been a striking rise in the number of clerical and other white-collar workers. Proprietors and managers are comparatively fewer. The number of professional, semi-professional, and technical personnel has increased in 50 years from little over a million to more than 5 million and is still expanding rapidly.

By 1950, as shown in figure I, the economically active population was composed roughly of ⅕ skilled and professional workers, over ⅕ semiskilled, ⅕ unskilled, ⅕ clerks, etc., and less than ⅕ owners and managers.

More recent figures, are as follows: The spaced groupings correspond to the categories used in figure I.

Major Occupation Group of Employed Persons, United States, Week of April 4–10, 1954

| | Number (thousands) Both Sexes | Per cent | | |
|---|---|---|---|---|
| | | Both sexes | Male | Female |
| *Total Employed* | *60,598* | *100.0* | *100.0* | *100.0* |
| Professional, technical, and kindred workers | 5,689 | 9.4 | 8.2 | 12.0 |
| Farmers and farm managers | 3,905 | 6.4 | 9.0 | 0.6 |
| Managers, officials, and proprietors, except farm | 6,048 | 10.0 | 12.1 | 5.2 |
| Clerical and kindred workers | 7,894 | 13.0 | 6.6 | 27.5 |
| Sales workers | 3,957 | 6.5 | 5.9 | 7.9 |
| Craftsmen, foremen, and kindred workers | 8,248 | 13.6 | 19.0 | 1.4 |
| Operatives and kindred workers | 12,363 | 20.4 | 21.2 | 18.6 |
| Private household workers | 1,828 | 3.0 | 0.1 | 9.5 |
| Service workers, except private household | 5,229 | 8.6 | 6.5 | 13.4 |
| Farm laborers and foremen | 2,011 | 3.3 | 3.3 | 3.3 |
| Laborers, except farm and mine | 3,426 | 5.7 | 7.9 | 0.6 |

"Operatives" in the above table are persons engaged in manual work, usually of a routine nature requiring moderate or little training and moderate dexterity, and often requiring moderate or little physical force. Examples are: apprentices in many trades, chauffeurs and truck drivers, miners, machine operators in textile and clothing plants, private seamstresses. In skill these people occupy a wide range between the skilled craftsman on the one hand and the manual laborer on the other.

*Source:* U. S. Bureau of the Census release, series P-57, No. 136.

The proportion of persons in the professions, including lawyers, doctors, scientists, engineers, et al., has progressively increased during the 20th century. This is not surprising because the technological structure has grown deeper and more complex.

The proportion of proprietors, managers and officials declined during the 20th century. In part, the decline of the highly skilled white collar class—proprietors, managers and officials,—is offset by the increase of the professional class. As industry has grown larger and more technical, skilled, scientific technicians and highly qualified scientists take the place of the skilled administrative personnel.

Clerks and kindred white collar workers have increased enormously, when measured either absolutely or relatively. The problems of getting goods from the factory to the ultimate consumer have grown in complexity. The labor requirements of distribution have thus increased. This accounts for the enormous growth of white collar persons, who are essentially semi-skilled workers.

Skilled workers and foremen have shown a relative constancy through the 20th century, although their absolute numbers have increased with the growth of the total population. The reliance on skilled workers and foremen obviously grows as the production mechanism becomes larger and more complex. The use of single purpose machine tools and other labor saving devices has reduced the technical need for skilled workers as production personnel, but has increased their need as tool makers and machinists.

The growth of semi-skilled workers matches the growth of clerks and kindred workers. The growing automatic nature of production places more and more reliance upon the semi-skilled worker. It is these workers who control and operate the highly skilled machines. A semi-skilled worker can learn his job in anywhere from six weeks to six months. The machine, however, often represents thousands of dollars of investment and years of research and development.

The proportion and number of unskilled workers have decreased year by year in the 20th century. Muscle and brawn are no longer a prime requisite for industrial jobs.

As we have pointed out above, automation means the accelerated introduction of labor saving and capital saving devices. One can expect that the need for professional persons will rise. The engineers, the physicists, the scientists—the skilled professional, in brief—will be needed in greater numbers as technology advances. The trend reduction in relative requirements for proprietors, managers and other officials will probably continue. The requirement for these people is also reduced as the financial integration of industry goes on. The trend of increasing number of clerks, semi-skilled workers, will probably continue, while the tendency for the proportion of unskilled workers to decrease also is likely to obtain.

The need for skilled workers, on the other hand, is likely to expand. However, the nature of the skilled worker required is likely to change as automation progresses. The need for technicians and other highly trained workers is almost in direct proportion to the growing complexity of industry. The training of these skilled workers will probably become more intense and more industrially oriented. The study of electronics, hydraulics and mechanics will probably, to some extent at least, take the place of studies in electrical wiring, plumbing and machining.

Barring cyclical depression or war, it is almost a foregone conclusion that per capita income in the United States will increase in the foreseeable future. This increase in per capita income will result in more years of schooling for young people, higher standard of living for retired people, long periods of training for people already employed in industry and commerce. In brief, we as a nation probably will become rich enough to afford luxuries not available in the past. The result of such better living is to reduce the labor supply and to reduce the economic pressure in the society. This, in itself, means that automation, by increasing the standard of living, reduces the possibility of technological unemployment, because it reduces the potential labor supply, vis à vis the capital supply.

It is difficult to quantify the effect of better social amenities on labor supply, but surely it is appreciable. The reduction of the work year from 52 weeks to 50 weeks represents roughly a 4% decrease in working time. In 1950, 6% of our adult population had gone to college four years or more. It would not be surprising if, during the next generation, the proportion of adults who have had four years or more of college training more than doubled from 6% to 12%. This will not only increase the


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supply of professional persons, but will decrease the total labor force since these six or seven odd millions of people will have been out of the labor market for at least four years. Social attitudes, the mores of the society, the consumption function and industrial requirements indicate that the social changes related to automation in the offing do not make the future look black.

## VI

The business or capital aspect of automation or technological improvement is closely related to analytical discussion of employment.

Formal economic theory argues that a new technological device will be introduced if the total unit cost of production with the new device is less than the incremental or marginal cost of using the old techniques of production. Thus, this type of argument while logically impeccable, is beside the point in 20th century America. Technological improvement will, in fact, be introduced if its superiority over the old method of production is so great that the new technological device will pay for itself within a short space of time, say one to three years. In other words, the investment horizon of the modern business man is very brief indeed.

This short investment horizon of modern business implies that the tempo of innovation and of technological improvement is sufficiently great that the business man is not willing to take long range risks. He prefers to tie up his capital for only the shortest period of time. An incidental aspect of this rapid technological change is that, in the mind of the business man, the interest rate (cost of capital) becomes relatively unimportant. The reason is that new capital equipment is considered only when its superiority is so great as compared to the old device, that differences in efficiency of 1%, 2%, or 3% are of negligible importance. If man-hour productivity continues to increase at 2% to 3% per year, the percentage increase in the capital fund may be constant or increase slightly, but the absolute size of the fund will become very great indeed. The ability, then, to use technological improvement will be very great, especially since the size of the working population will increase, but slowly.

It is only a wealthy country which can afford to have short business horizons. European business men are more likely to think in terms of the mechanical life of a piece of equipment, rather than in terms of the piece of equipment paying for itself in one to three years.

The short investment horizon has another corollary which is extremely important. Because the American investment horizon is so brief and because technological improvements are occurring with such rapidity, the *volume* of decisions which business men have to make about capital improvement and capital equipment increases from year to year. With a long investment horizon, once the decision is made, the firm makes the best of it for the life of the capital good. With short investment horizons, decisions must be made with great frequency, and decisions which imply both economic and engineering knowledge, for novelty is always treading on the heel of novelty.

The fifth and final proposition then is: "In a changing world the innovation and technical improvement are rarely carefully weighed in the balance of costs and returns. No one knows what the future holds, except that technology is ever expanding. Therefore, new improvements must pay for themselves quickly, lest they become obsolete. The investment horizon is determined in great part by the rate of technological advance. The more rapid the latter, the shorter the former".

As time goes on, as the national income increases, the amount of capital accumulated each year will probably continue to increase. In the recent past, the rate of capital accumulation has been roughly constant. This means that the pressure on the business man to make improvements or find new products is growing ever greater. This also explains the extreme importance of scientific research and engineering research in the modern world. As time goes on, business will find it advisable to subsidize pure (that is, non-purposive) research in addition to subsidizing applied and developmental research.

We can conclude, then, that automation as a special type of technological improvement is a mark of an expanding economy. On the whole its effects are beneficial, but the process of expansion and economic progress is often painful and destructive to old ways of doing things.


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# Trends in Plant Layout and Design

**By Dr. Eugene Richman**

*Associate Professor, Industrial and Engineering Administration Department, Cornell University*

The functions of Plant Design and Plant Layout should first be differentiated. Plant Design is used here to mean the over-all design of an enterprise. It includes the origin of the enterprise, the acquisition of capital, the plant location, and all sales and production preplanning for the physical requirements of men, materials and machines.

Plant Layout Engineering refers only to the optimum selection and placement of machines, equipment and service facilities within a structure, together with the design of the best structure possible to house these facilities from both a cost and efficiency point of view.

The functions of Plant Layout and Design are often confused and the terms used interchangeably. Perhaps this stems from the fact that in the early days of industrialization these functions were generally combined and were usually performed by the same individual. The first factories were simple, barn-like structures whose primary purpose was to provide shelter for a number of machines all under one roof.

## Present Development

The present state of the development of the areas of Plant Layout and Design can perhaps be seen best from an examination of the present tendencies in plant location, in building design, in layout and materials handling, and in layout tools.

The trend in plant location is towards the dispersal or decentralization of industry in smaller cities or in outlying areas of large cities. This is because of both economic reasons and strategic (military) considerations.

The factory is tending more and more to become a shell over an industrial process. Buildings are being designed for flexibility, for expandability, and even for demountability. The trend is toward modular coordination, the dimensioning of all units as multiples of a basic unit or module. Heaviest demand seems to be for the single story building. Buildings are being oriented to take best advantage of site and surrounding terrain.

New construction materials such as prestressed concrete, laminated beams, aluminum "lumber", nailable steel, glass panelling and blocks, stainless and porcelain enameled siding, plastic panels, and various "sandwich" materials combining plastic, plywood and metals are coming into widespread use.

Advances in materials handling are making a great change in building requirements and efficiency. Handling developments have been too numerous to fully describe in this report. A few developments have been the spectacular growth of conveyorization and palletization, the use of sideloading, self-aligning, telescoping and positioning equipment and the variety of transfer machines for use in automated operations. While the trend towards automation tends to complicate building design to house production equipment, it is resulting in smaller employee density (space per employee). In the past, the production process appears to have been designed about unit loads which *people* were capable of handling, that is, generally under fifty pounds. Automation is allowing for the design of processes based on loads which are now limited only by the capacity of the *machines* used.

There has been a considerable improvement of the tools of the layout man. Refinements and developments in a number of photographic and vapor reproductive processes using paper, acetate and other plastic materials have made for better and cheaper two dimensional layout records. The use of a variety of layout tapes for walls, stairways, conveyors, flow lines, etc., have helped to eliminate much of the drafting time previously required. The availability of accurate and standardized two dimensional layout templates of film and paper, and of three dimensional templates of wood, metal, and plastic have done much to simplify the work of the plant layout engineer and has made for more presentable and less costly layouts.

## New Concepts

The future of plant layout and design seems destined to be affected not only by new materials, handling equipment, and processes but also by new concepts and methodologies.

As with other specialists, many plant layout engineers of the past decade have been examples of highly trained but unintegrated individuals. There appears to have been a lack of coordination between those who design and manage the enterprise, and those who design the layout. The layout man cannot properly design a plant without knowing such things as the cost and value to the company of quality and safety; the trends in the particular industry and their probable effect on the length of production runs and on obsolescence of machines and materials; and the probable effect on the particular industry of changes in local, national and international economic and political affairs.

The specialization of knowledge has placed a premium on the ability to integrate vast amounts of information and seemingly unrelated data. The plant designer is faced with the design of a complex system. The layout engineer

is faced with a somewhat less complex, but nevertheless, staggering system to optimize. These needs have resulted in the creation of new approaches. The emergence of an interdisciplinary team approach to the solution of complex problems seems to be a most promising avenue for the plant design and layout engineers. Many of the methodologies being developed by operations research and systems analysis groups appear to be exactly what is needed by plant layout and design personnel.

Some of the promising analytical tools and methods are linear programming, game theory, decision theory, gaming, information theory, queueing theory and the use of servo, hydraulic, and thermodynamic analogs.

Linear programming has been used to determine the most profitable mixes of raw materials and products. It has been used for scheduling of work to machines, for wage policy determinations and for inventory control. It has numerous applications in Plant Design work such as the solution of plant location and warehouse location problems, for storage and materials handling problems, for determining optimum quality policy and many others.

The theory of games is especially useful to the Plant Design engineer in connection with decision models. Possible applications are plant location decisions, production and handling equipment selection decisions, and a whole host of equipment placement decisions.

The various analogs such as servo, hydraulic, and thermodynamic models may prove most useful in connection with materials flow and handling problems. For example, if materials flowing throughout a plant is likened to current flowing in a circuit, with storage areas represented as condensers, and bottlenecks as resistors, then control of such a physical circuit may respond to the analogous treatment which an electronic solution may suggest.

Queueing theory models (waiting lines) also appear to have great potential in materials flow, handling and storage problems as well as for problems involving the determination of a suitable number of machines and personnel for plant production and service facilities. Typical problems might be the number of storage areas and/or attendants to service a given number of materials handlers; the determination of optimum bank and float sizes; the determination of the best number of handlers to supply a given number of machines; and the design of optimum conveyor and materials handling systems.

Gaming may be viewed as a complete trial of a proposed system for the purpose of determining the characteristics of the system by repeated manipulation of some model which has been designed so as to afford cheap and easy construction and operation. Thus, gaming has the effect of introducing change, before actually making a change, and has far reaching implications in Plant Design work. It should provide a most useful method for making "dry runs" for innumerable plant modification proposals.

The plant design and layout engineer appears to be intuitively conditioned for the use of these methodologies by virtue of his engineering background and his experience in manipulating two and three dimensional layout models. These newer tools should allow him to devise and manipulate mathematical models to simulate the physical models now in use. He may then be able to test or visualize the results of the mathematical models by using them in conjunction with the present physical ones. The use of these analytical methods and data-processing machines should help him to include and incorporate the vast amount of data needed for the solution of layout and design problems.

A word of caution is necessary. Many of the analytical methods are still crude and incapable of handling many variables. Many assumptions coupled with the use of mathematical models may be unrealistic, and most layout and design engineers of today are not conversant with these newer techniques. Yet these approaches and methodologies should allow the plant layout and design engineer of the future to make great contributions to the industry of tomorrow.


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In the December 1954 and subsequent issues of the NEWSLETTER, National Headquarters announced the availability of "The Fatigue Allowance in Industrial Time Study" by AIIE Past-President M. A. Payne (1949).

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# Comparison of All-Day Time Study with Work Sampling by Use of Analysis of Variance

**By L. J. Cote**

*Statistical Laboratory, Purdue University*

**and B. J. Scott**

*Lt., U.S.N.*

The problem, presented by a representative of the Navy's Bureau of Aeronautics, was to compare the merits of All-Day Time Study versus Work Sampling, or Ratio Delay, as methods of work measurement for variable cycle and indirect labor activity. The information is to be used for estimating budgetary and manpower requirements. The specific field of application that was of interest was supply and accounting, but the methods of this experiment may be used in any situation in which a group of workers is performing approximately the same type of work and yet not acting as a single crew.

Some factors of the original comparison, such as the skill of the analyst and the amount of training required, were subjective and these are not included in this paper. However, the relative accuracy of each sampling method, and the time required to obtain this accuracy were objectively comparable as the results of a statistical analysis of variance, using techniques and formulae developed for this type of problem.

Quite naturally, the methods used in the collection of data were similar to those commonly used in industry. This was desirable, since the intent was to compare current methods and not to devise new ones. Four operators in the Supply Department of the U. S. Naval Ordnance Plant, Indianapolis, Indiana, were studied for two days each (a total of eight days) using accepted all-day time study procedures. Then these same operators, plus four others from the same work areas and who performed approximately the same type of work, were studied for four days under a work sampling plan. Since the purpose of the study was not to set standards, the operators were not rated. Thus the comparisons are for work accomplished, not work which should have been accomplished.

The quantities to be estimated are the mean proportions of time per man per day spent on the various functions. The functions performed within the department and considered to be discrete were receiving, issuing, screening, delay, and X-tra. The terms receiving and issuing are in common use and need no definition. Screening consists of verifying that material is properly catalogued and stored, and maintaining records on repairable material. Delay includes both avoidable and unavoidable delay, and personal time except for the lunch period. X-tra was devised as a catch-all to cover functions not performed in each section, such as cleaning, relocation of material, supervising, etc. Table 1 in the Results contains the estimated mean proportions of time spent on these functions. This table also contains the standard deviations of the estimated mean proportions and estimates of the components of error.

As understood by the writers and as set forth in current literature, some industrial organizations use the following assumptions in their work measurement programs. Whether the technique is "standard" time study of machine operators or assembly line mechanics, or a work sampling study of indirect labor of crews or individuals, they tend to assume:

a) that the process is stable; i.e. that the daily variability is small.

b) that the one, two, or more machines or work stations studied are typical of all machines or work stations performing that specific job, and if a rate is set or work load capability estimated for this small sample, it should be applicable to similar machines or work stations.

c) that the variability among the different operators or crews is negligible or can be reduced to a negligible value by rating.

If these assumptions are correct, or nearly so, there is not much justification for using more detailed and complicated procedures for work measurement. However, in the situation studied here some of these assumptions proved incorrect.

In order to use work measurement for projecting information forward to estimate future capabilities or requirements, it is important that the process be stable or nearly so. A feature of the procedure described in this paper is that quantitative measures of this stability are estimated. By use of statistical methods it was desired to eliminate as much subjective influence as possible and to

estimate human and job variability. One interesting and very pertinent point is that the use of the binomial formula alone to compute the accuracy level obtained in a work sampling program ignores sources of error of larger magnitude, namely the variation among men, and the day-to-day variation of the men. An evaluation of the precision afforded by a sampling scheme must take these sources of error into account.

**Statistical Considerations**

The arrangement of the observations was made with three purposes in mind: To make estimates of the average proportion of time per man per day spent on various functions of the work; to estimate the magnitude of the components of error; and to compare the results of the two types of sampling for differences in bias.

The basic measurement made on a worker (number $i$) on a day (number $j$) is $X_{ij}$, the proportion of time he spent performing a particular function. This is considered to be the sum,

$$X_{ij} = \mu + w_i + d_j + (wd)_{ij},$$

in which $\mu$ is the general average over all workers and days of the proportion of time spent at that function. The other quantities are, $w_i$ the average (over days) amount by which worker $i$ deviates from $\mu$, the general average; $d_j$ the average (over workers) amount by which day $j$ deviates from $\mu$; and $(wd)_{ij}$ the residue or worker $i$'s residual variation on day $j$. The assumptions are that the workers work independently of each other and that the $w$'s of the ones we have chosen to observe form a random sample from a large population of $w$'s whose mean is zero and whose standard deviation is $\sigma_w$. The latter is the measure of variability among workers. Similarly the days are assumed to be random as are the day-to-day variations of the workers. The standard deviations are denoted respectively $\sigma_d$ and $\sigma_{wd}$. The squares of these standard deviations are called the components of error or of variance. The estimation of these quantities is accomplished by the technique of variance components analysis.[1]

For purposes of mathematical analysis, a general sampling plan was constructed which embraces both types under study. From the area of department of interest, $a$ men are chosen and $k$ of them are observed per day until each man has been observed a total of $b$ days. The number of days spent is $ab/k$. In the case of work sampling, each man is observed at $n$ random times per day. The quantities $a$, $b$, $k$, and $n$ determine the plan and should be chosen by the analyst to minimize the standard deviation of the estimated mean proportion, at the same time keeping them within practical limits.

[1] For general discussion, see Anderson and Bancroft, "Statistical Theory in Research", p. 313. For application to a sampling problem, see J. M. Cameron, "Use of Components of Variance in Preparing Schedules for the Sampling of Baled Wool", *Biometrics*, v. 7, No. 1 (1951).

For all-day time study the quantities $X_{ij}$ are measured directly and the estimate of $\mu$ is the average of the measurements,

$$\bar{X}_C = \frac{1}{ab} \sum_i \sum_j X_{ij}. \qquad \text{Eq. 1}$$

For work sampling the measurement is $p_{ij}$, the proportion of the $n$ times that worker $i$ was observed on day $j$ performing the function of interest. The estimate in this case is:

$$\bar{X}_R = \frac{1}{ab} \sum_i \sum_j p_{ij}. \qquad \text{Eq. 2}$$

The precision of estimates of this sort is measured by the standard deviation. In the case of all-day time study this works out to be:

$$\sigma_C^2 = \frac{1}{a} \sigma_w^2 + \frac{k}{ab} \sigma_d^2 + \frac{1}{ab} \sigma_{wd}^2. \qquad \text{Eq. 3}$$

For the work sampling case, it must be noted that the $p_{ij}$ are affected by a sampling error which causes them to differ from the true value $X_{ij}$:

$$p_{ij} = X_{ij} + \delta_{ij}.$$

This difference, as the error in a proportion, is well known to have mean zero and variance $\frac{1}{n} X_{ij}(1 - X_{ij})$. Since the $X_{ij}$ are themselves random, the overall variance of $\delta_{ij}$ must be found using conditional expections. It is:

$$\frac{\mu(1-\mu)}{n} - \frac{\sigma_w^2 + \sigma_d^2 + \sigma_{wd}^2}{n} \qquad \text{Eq. 4}$$

With this additional component of variance we obtain the variance of $\bar{X}_R$:

$$\sigma_R^2 = \frac{1}{a} \sigma_w^2 + \frac{k}{ab} \sigma_d^2 + \frac{1}{ab} \sigma_{wd}^2 - \frac{\sigma_w^2 + \sigma_d^2 + \sigma_{wd}^2}{nab} + \frac{\mu(1 - \mu)}{nab} \qquad \text{Eq. 5}$$

This is the same as Eq. 3 except for the last two terms. The advantages of one or the other plan depends, however, on the ranges of $a$, $b$, $k$, and $n$ available. The combination of values in each range which gives the smallest variance determines the best plan. Generally speaking, the forms of $\sigma_C^2$ and $\sigma_R^2$ indicate that their minimum values are obtained when $a$, $b$, $k$, and $n$, in order of importance, are chosen large. If $ab/k$, the number of days spent in observation, is a measure of cost, and if $k$ is substantially larger for work sampling than for time study, the smaller variance will be obtained from work sampling unless the components $\sigma_w^2$, $\sigma_d^2$ and $\sigma_{wd}^2$ are unusually small. Selection of a plan should begin with estimation of the components of variance from a preliminary study. Then the practicable plans can be compared as to their precision by using the above formulas.

In the present paper the all-day time study was done with $k$, the number of men observed in a day, equal to 1.

The work sampling data were taken with $k = a$. These special choices of $k$ enable the observations to be arranged into simple experimental designs; for $k = 1$, a one way analysis of variance, and for $k = a$, a randomized block. For intermediate choices of $k$, the observations can be arranged, if some care is taken, into an incomplete block design which lends itself to easy calculations of the components of variance estimates. The two analyses of variance tables for $k = 1$, all-day time study, and for $k = a$, work sampling, appear below.

The expected mean squares are equated to the numerical values calculated from the data. For the work sampling case, the estimate of $\mu$ is substituted into the expression for expected mean square. The resulting equations are solved for the components. This method gives unbiased estimates, but they may come out negative when the true component is small. Where this happened, the estimates are reported as zero in Table 1.

## Results

Table 1 contains a digest of the statistical estimates made. The $\bar{X}_R$ and $\bar{X}_C$ are sample means, and they are the estimates that a time study analyst would seek to obtain. The $\sigma_R$ and $\sigma_C$ are the standard deviations of these measures of their precision.

The components of $\sigma_R$ and $\sigma_C$($\sigma_d$ , $\sigma_w$ , and $\sigma_{wd}$) are used in Eq. 3 and Eq. 5 to compute the standard deviations of the estimates. They are included here to give a comparison of the sizes of the quantities, so that the reader may judge how much each contributes to the variation of the estimates. For example,[2] in Eq. 5 it is seen that for the function of issue the variation among men contributed .00496 to the variance while the sampling variation for this function gave .00043. This shows that, compared to the other components of error, the sampling variation is rather small.

A separate set of tests was made by comparing the estimates under all-day time study and under work sampling for the four men common to the two samples. The numerical results are not included, but all the tests showed insignificance at the 5% level. It may then be concluded that for this experiment the bias was too small to detect with the relatively small sample size.

Although no bias was found in the means, the $\sigma^2_{wd}$ for work sampling for all the functions but one (with usable data) is larger than the combined term, $\sigma^2_{wd} + \sigma^2_d$ , of all-day time study. This suggests that the component of error due to each man's day-to-day variation is smaller for all-day time study than for work sampling. Though

TABLE 1

*Receipt Issue Delay Records Screening X-tra*

| | | | | | | |
|---|---|---|---|---|---|---|
| **Work Sampling** | | | | | | |
| $\bar{X}_R$ | .247 | .271 | .328 | .107 | .006 | .103 |
| $\sigma_R$ | .080 | .079 | .052 | .050 | * | * |
| $\sigma_w$ | .152 | .199 | .114 | .119 | * | * |
| $\sigma_d$ | .060 | .000 | .000 | .000 | * | * |
| $\sigma_{wd}$ | .173 | .157 | .127 | .131 | * | * |
| **All-Day Time Study** | | | | | | |
| $\bar{X}_C$ | .229 | .382 | .295 | .050 | .010 | .092 |
| $\sigma_C$ | .090 | .133 | .091 | .031 | * | * |
| $\sigma_w$ | .148 | .254 | .155 | .044 | * | * |
| $\sqrt{\sigma^2_d + \sigma^2_{wd}}$ | .083 | .115 | .137 | .061 | * | * |

* Job rarely performed, sample size too small for data to be used.

[2] In this study, the number of times per day a man was observed was not constant. The factor 9.8 can be used for $n$ in (5).

| Name | Computing formula for sum of squares | Degrees of frdm. | Expected mean square |
|---|---|---|---|
| | **k = 1, A.D.T.S.** | | |
| Among workers | $\frac{1}{b}\sum_{i=1}^{a}\left(\sum_{j=1}^{t} x_{ij}\right)^2 - \frac{1}{ab}\left(\sum_{i=1}^{a}\sum_{j=1}^{b} x_{ij}\right)^2$ | $a - 1$ | $b\sigma^2_w + [\sigma^2_d + \sigma^2_{wd}]$ |
| Within workers | Total minus Among | $a(b - 1)$ | $[\sigma^2_d + \sigma^2_{wd}]$ |
| Total | $\sum_{i=1}^{a}\sum_{j=1}^{b} x^2_{ij} - \frac{1}{ab}\left(\sum_{i=1}^{a}\sum_{j=1}^{b} x_{ij}\right)^2$ | $ab - 1$ | — |
| | **k = a, W.S.** | | |
| Workers | $\frac{1}{b}\sum_{i=1}^{a}\left(\sum_{j=1}^{b} p_{ij}\right)^2 - \frac{1}{ab}\left(\sum_{i=1}^{a}\sum_{j=1}^{b} p_{ij}\right)^2$ | $a - 1$ | $b\sigma^2_w + \sigma^2_{wd} + \frac{1}{n}[\mu(1 - \mu) - \sigma^2_w - \sigma^2_d - \sigma^2_{wd}]$ |
| Days | $\frac{1}{a}\sum_{j=1}^{b}\left(\sum_{i=1}^{a} p_{ij}\right)^2 - \frac{1}{ab}\left(\sum_{i=1}^{a}\sum_{j=1}^{b} p_{ij}\right)^2$ | $b - 1$ | $a\sigma^2_d + \sigma^2_{wd} + \frac{1}{n}[\mu(1 - \mu) - \sigma^2_w - \sigma^2_d - \sigma^2_{wd}]$ |
| Interaction | Tot − Days − Workers | $(a - 1)(b - 1)$ | $\sigma^2_{wd} + \frac{1}{n}[\mu(1 - \mu) - \sigma^2_w - \sigma^2_d - \sigma^2_{wd}]$ |
| Total | $\sum_{i=1}^{a}\sum_{j=1}^{b} p^2_{ij} - \frac{1}{ab}\left(\sum_{i=1}^{a}\sum_{j=1}^{b} p_{ij}\right)^2$ | $ab - 1$ | — |

this cannot be tested statistically, the indication is interesting. If this is a real effect, it may be due to the analyst's relationship with the workers in this study. It would tend to make the all-day time study more precise. This advantage, however, is more than compensated for by the greater efficiency of the work sampling method. Whereas the latter required only half as many days of observation, the standard deviations of the estimates are about the same size as those of the all-day time study estimates.

**Conclusions**

A comparison of the means and standard deviations for all functions indicates that the work sampling plan was better than the all-day time study for estimating the work performed. Work sampling produced as accurate an estimate, and, yet, only one-half the amount of time was spent on collection of data.

For practical use of the analysis of variance technique in a work measurement program, the time study analyst, by using either all-day time study or work sampling, may take the data collected during the first two days for an analysis of variance to obtain an estimate of the sampling error. This estimate may be obtained by use of either Eq. 3 or Eq. 5. Although the values obtained from the first two days' sampling will give very rough estimates, they can be used to indicate about how many days (or observations) will be necessary to achieve the desired accuracy.

The estimates may be defined at the end of each day of data collecting to indicate the accuracy obtained. As indicated above, in almost all situations of variable-cycle or indirect labor activity, work sampling will be the best procedure, and the sampling plan should include as many workers as is practicable.

*Acknowledgement.* The authors would like to acknowledge the contribution to this work of Professor H. H. Young of the Department of Industrial Engineering, Purdue University, and to extend their thanks to the Commanding Officer and members of the Supply Department at N.O.P.I. for their assistance in the collection of data.

## POSITION AVAILABLE

Position as Head of Industrial Engineering Department open. Requires background of progressively responsible management positions in industry or government. Good record of publications. Research and teaching experience desirable. Age, 35–50; salary, open; position to be filled prior to September, 1956. *Write to* Chairman, Nominating Committee, Industrial Engineering Department, The Pennsylvania State University, University Park, Pennsylvania.

**HERE AND THERE**—INSTITUTE INTERESTS

The Washington D. C. Chapter has announced that the AIIE National Conference and Convention will be held at the Shoreham Hotel in Washington on May 17, 18, 19, 1956. Although the program is still in the planning stages, it was announced by James W. Thompson, General Co-Chairman of the Conference and Convention Committee, that the Conference will include approximately two days of instruction-type sessions. During these sessions about ten specific industrial engineering analytical and mathematical tools will be discussed in sufficient detail to permit those present to "take them home and apply them". In addition, papers describing specific new tools for utilization by the industrial engineer as a result of technical advances and growth of such industries as nuclear energy and electronics will be discussed.

Washington is particularly beautiful during the month of May, and it is hoped that members attending the Conference and Convention will bring their families to enjoy the hospitality and beauty of our Nation's Capital.

The first place winner in the National Student Member Essay Contest for 1955 was announced by National Headquarters. He is Donald Lee Ross, a senior at the School of Industrial Engineering and Management at Oklahoma A & M.

The subject of the winning essay was "Why Am I a Student in Industrial Engineering?" Mr. Ross proved to be most adept at expressing the student's concern for his future profession. He is a student member of AIIE and resides at 13B College Courts, Stillwater, Oklahoma. Congratulations!

The profession of industrial engineering lost a colorful figure in the death of John Avent in August. He was connected with Georgia Tech before building up his own consulting firm. He was especially active in the Atlanta Chapter of AIIE and took considerable interest in furthering industrial engineering throughout the university systems in the southeast. His consulting firm continues under the direction of J. S. Creel and E. B. Russell, who were associated with Mr. Avent for quite some time.

On Friday, September 30, 1955, at Morgantown, West Virginia, J. L. Southern, Executive Secretary of AIIE, presented a charter to the West Virginia University Student Chapter. This was the 25th student chapter charter so rendered.

Our national president, Ed Slagle, presented the charter to the Great Salt Lake Chapter on September 13th, bringing the number of senior chapters at that time to fifty. The president of the new chapter is Grant Schaumberg, whose address is P.O. Box 510, Provo, Utah. Congratulations and welcome to our new members. Let us hear of your activities.

On October 1 National Headquarters mailed dues statements to 3631 members and affiliates. Each chapter has received dues statement recaps, rosters, and all corrections on rosters and statements up to that date. It is now the chapter's and members' responsibility to see that all 3631 statements are returned to Columbus for processing. It is hoped that no memberships will be lost due to change of address and lack of chapter interest in seeing that dues are returned promptly.

The membership dues are now on an October-to-October basis, which is a most sensible plan because of the resumed activity in some chapters after the summer vacation.

The Constitution revisions mailed out during the summer months were overwhelmingly passed. This was the second vote on these revisions and was made necessary by a balloting procedure change requested at the last national convention.

With the passing of the Constitution changes, Dr. Alex Rathe was appointed third Board Member-at-large.

# The Characteristic Ratio

**By Alan J. Levy**

*Industrial Engineer, Bulova Watch Co., Flushing, New York*

To effectively study any system or institution, it is necessary to use some form of quantitative analysis—obtain numbers—and make judgments about those numbers. The question thus arises, what numbers should be studied and how to use them to arrive at a conclusion. This article recommends a simple means of devising a numerical standard to judge the level of efficiency of any operation or organization.

The guide that I am recommending I will call a characteristic ratio. The ratio is developed by relating the important output of an operation with the principal input and giving this relationship meaning in connection with the total operation. As an example, the Farm Bureau Insurance Company has developed a ratio of the number of in-force insurance policies to the number of clerks processing those policies. Using this ratio year in and year out, the management has a unit of measure to judge the efficiency of their clerical staff, to see if there are really improvements taking place and if the company is running efficiently. Here the output, administration of in-force insurance policies, is related to the input, the number of clerks necessary to process these policies. Similarly, a characteristic ratio may be developed for any operation by properly relating the important characteristics of the outputs and inputs.

The use of ratios to judge operations or compare competing companies or divisions is a common control tool in use throughout industry today. Financial statements, progress reports, the results of a company's production are all turned into ratios to give meaning to the raw figures. Some of these ratios are informative and some of them are misleading, and much has been written evaluating this or that particular ratio. The point here is to highlight the basic aspects of a characteristic ratio and remind the reader that it is an important tool of control and judgment.

There are several principal advantages in using a ratio. It is easy to compute—the basic figures should already be available in the operation of the company. These figures may be the daily production, number of employees, cost of purchases, total or departmental sales. A ratio gives a measure of the operation during different time periods even though there may be large changes in the systems or mechanization or personnel. It may be computed when other measures are not available. In many industries, there are enough figures available about competitors to compute ratios on one's competitors or the industry as a whole and thus judge one's company against other operations. In fact, many trade magazines publish at least one industry ratio and enough raw data to allow easy computation of others.

The principal disadvantage is a matter of judgment—deciding what is and is not a healthy ratio. Such judgment depends upon the professional ability of the men constructing and using a characteristic ratio. There have been both good and bad results from using ratios, and it is the competence of those using a ratio that will guarantee the results. The danger of misusing a ratio cannot be overemphasized. There are many ratios used as common guides that apply to some situations but not to others, that apply to some companies, not to others. The characteristic ratio being recommended here is one where the fundamental input is related to the fundamental output. The error usually encountered in ratio construction is that the interesting, but not the fundamental aspects of a situation are related to each other. When a ratio is properly constructed, it must be used carefully and wisely, that is, the standard of evaluation must be one that understands the real meaning of the relationship.

Well, what can be measured? In financial circles, the balance sheet and profit and loss statement have a whole series of accepted ratios. The current ratio shows the relationships between current assets and current liabilities with a standard between 3 to 1 and 2 to 1 indicating a normally healthy structure—that is, there are at least two to three current assets to current outstanding items. Stock market devotees like to watch the Price to Earnings ratio, comparing the current market price with the companies' earnings per share. This ratio must be judged against economic conditions; a deflated economy should have a price-earning ratio from 7:1 to 9:1; while an inflated economy can safely show a ratio from 14:1 to 16:1. There are many, many financial ratios that are discussed and evaluated in numerous fine works of corporate finance.

The standards for repairing a watch, or any other repair, may be converted into a ratio by computing the ratio of the number of watches repaired each period with the number of watchmakers employed. Repair and maintenance operations, by their nature of special work, tend to avoid the setting of standards. But over a period of time, a picture of the efficiency of a department confronted by repairs to standard items may easily be shown.

Absenteeism should be measured as a ratio of the total number of employees absent to employees on the job. It is best to compute this figure in terms of a percent to give the percent number of people absent—or number employed. Employed absence is a negative input and it is

compared to the output of employees on the job. The same is true of the accident rate.

Highway designers use a highway capacity ratio to compare maximum quantity of automobiles that can travel on a highway with the number that are actually using the road or will use the highway. They can then determine if a road is adequate or how much highway capacity must be added.

Many, many more examples could be cited—those interested will find a large list in the *Production Handbook*. The point emphasized in this article is that a characteristic ratio may always be constructed by relating the basic input vs. the basic output of any activity. The construction of a ratio requires accurate definition and identification of the fundamental input-output relation and evaluation of the results involves mature judgment.

# READER COMMENTS

### Humanation

More and more industrialists are discovering the advantages of employing humans in industry. Day by day they are becoming increasingly aware of the many advantages involved in substituting humans for machines. Among the many advantages are:

1. They maintain themselves.
2. They provide their own source of power.
3. They occasionally think for themselves.
4. They require no oil.
5. They are highly mobile.
6. There is no initial cost.
7. There are no depreciation charges.

—*Human Age*, August 1975
*Dan Flanders, M.I.T. '50*

### Something About Nothing

The following was submitted to me, and I thought other JOURNAL readers might enjoy it.

*Robert H. Roy*

No matter what we do, most of us are interrupted from time to time by the request for a document euphemistically entitled a progress report. Because of their tacit assumptions, they are often a source of chagrin to otherwise phlegmatic scientists; for it is difficult indeed to write something about nothing.

Balm for the writhings and groans of the hapless individuals who must regularly wrestle with a progress report is now here. This valuable contribution to the progress of science is known as the standard progress report—it can be used anytime, anywhere. It is the result of long and arduous study by William Cohen, China Lake, California. As freely translated below, it is expressly for unfortunates who otherwise face extinction. Cohen says he never uses it himself. Type in batches of 100 and then date and sign a year's supply. Be sure the secretary omits the translations.

*Standard Progress Report for Those with No Progress to Report*

During the report period which ends _____ (fill in appropriate date) considerable progress has been made in the preliminary work directed toward the establishment of the initial activities. (We are getting ready to start, but we haven't done anything yet.) The background information has been surveyed and the functional structure of the component parts of the cognizant organization has been clarified. (We looked at the assignment and decided that George would do it.)

Considerable difficulty has been encountered in the selection of optimum materials and experimental methods, but this problem is being attacked vigorously and we expect that the development phase will proceed at a satisfactory rate. (George is looking through the handbook.) In order to prevent unnecessary duplication of previous efforts in the same field, it was necessary to establish a survey team which has conducted a rather extensive tour through various facilities in the immediate vicinity of manufacturers. (George and Harry had a nice time in New York.)

The Steering Committee held its regular meeting and considered rather important policy matters pertaining to the over-all organizational levels of the line and staff responsibilities that devolve on the personnel associated with the specific assignments resulting from the broad functional specifications. (Untranslatable—sorry.) It is believed that the rate of progress will continue to accelerate as necessary personnel are recruited to fill vacant billets. (We'll get some work done as soon as we find someone who knows something.)

From *Chemical and Engineering News*
December 15, 1954

# RECENT READABLES

## AUTOMATION

"Digital Automation", by M. L. Klein, F. K. Williams, and H. C. Morgan, *Instruments and Automation*, page 1716, October 1955.

This is the first in a series of articles designed by the authors to be a simple, practical working manual on the subject. The series is intended primarily for instrument and electronics engineers; however, the authors claim that it is written at a level understandable to all engineers. A basic knowledge of electricity, electron tube circuits and elementary mathematics through calculus is required. This first article deals with basic definitions, sequence control, simple Servo control, Data reduction systems, feedback control, automatic control, continuous vs. digital control and quantization and computers.

"Digital Computers—General Purpose and DDA", R. F. Walz, *Instruments and Automation*, page 1516, September 1955.

This article is based on a talk given at the First Automation Exposition last year. The functions and operating characteristics of general purpose computers and digital differential analyzers (DDA) are discussed. Typical problems involving differential equations are discussed to indicate their adaptability to DDA.

"Industrial Uses of Special Purpose Computers", by A. H. Kuhnel, *Instruments and Automation*, page 1108, July 1955.

Whenever a computing function is required full time, a special purpose computer may be the economic solution. The author gives examples of control of a punch machine requiring computed numbers of various gage pieces, control of a milling machine for contour milling or turbine blades, and a special purpose Data Processor. Analysis and design of the computer approach is discussed in detail. A case history is utilized to illustrate.

"How Computers Can Help to Create Their Own Programs", by B. Conway, *Office Management*, page 24, October 1955.

The most critical, time consuming phase in conversion to electronic data processing is the programming of various routines for computer processing. This definitive article outlines methods by which the machines themselves can do a significant part of the programming. Although there are some disadvantages to automatic coding, most programmers maintain that the positive points far outweigh the negative and the trend is toward more and more automatic coding, with special attention to the possibility of such coding in commercial applications.

"What Automation Means to America", C. W. Boyce, *Factory Management and Maintenance*, page 84, September 1955.

A comprehensive analysis by the Associate Editor covering such questions as (1) the effect on manufacturing, (2) the union's attitude on preserving jobs, (3) the argument against shorter hours, (4) the labor demand and the labor supply in 1975, (5) the effect of automation on obsolescence, and (6) the future of automation. Following the author's analysis are brief articles by twelve key men concerning their views on automation and the author's article.

## COST REDUCTION

"Better Machine Inventory", by C. G. McCabe, *Factory Management and Maintenance*, page 134, September 1955.

How an aircraft company uses equipment inventory cards to more effectively plan plant layout, optimize machine loading, provide up-to-date cost records, closer equipment control, and improved preventive maintenance. Basis for the whole program is a six digit numbering system which identifies each piece of equipment on the plant. Repairs are posted to the cards via the work order system. Installing the system took six months which involved typing history and repair cards for some 3,060 items covering 65 types of equipment, and applying decals and plates.

## INVENTORY CONTROL

"Scientific Inventory Control", F. H. Killorin, *Modern Materials Handling*, page 111, October 1955.

"Every cost attendant upon creating and maintaining an inventory can be reduced to either the cost of ordering or cost of carrying." The author presents an illustrative example which indicates how much to order and when. The example is presented along with tables and charts which are used to analyze for optimum inventory levels.

"Using Computers to Match Production and Seasonal Trends", by B. Kruse, *American Business*, page 12, October 1955.

A case history of how one clothing manufacturer utilizes a computer in combating the vagaries of the women's fashion market. The computer is used to provide sales and production figures needed early enough to adjust the operation according to seasonal trends. Inventory levels are adjusted on the basis of information furnished by the computer. This has meant that this company has been able to fill a half-a-million dollars a year worth of orders which it would once pass up with a less balanced midseason and late season inventory.

## MATERIALS HANDLING

"Applying Engineering Economics to Materials Handling—Part I", J. B. Day, *Modern Materials Handling*, page 117, October 1955.

Part I in a series of articles that take fundamental economic principles and apply them to practical problems of materials handling. The author presents five (5) basic rules as a basis for materials handling equipment selection and production or service planning. A check list for each of the five rules is offered as a guide to effective analysis.

"Consider the Cable Conveyor", R. B. Voet, *Modern Materials Handling*, page 123, October 1955.

The cable type trolley conveyor is becoming of growing importance in the overhead conveyor field. Designed for light duty applications where standard chain conveyors of heavier construction are often at a cost disadvantage, cable conveyors have most of the operating advantages of standard trolley conveyors plus some application tricks of their own. This article gives the facts concerning designs, capacities, attachments, and principal uses.

"How to Figure Your Industrial Truck Costs", W. A. Meddick, *Iron Age*, page 103, September 22, 1955.

The two important questions materials handling men are constantly faced with are: (1) what makes up operating costs of industrial trucks, and (2) what to do about lowering them. The author presents a convincing argument for the maintenance of proper records in order to answer these questions. A check-list of factors to consider in developing these costs is presented.

"Which Power Package For Your Fork Truck or Tractor", Editors, *Modern Materials Handling*, page 105, October 1955.

Those in the market for a new Fork Truck or tractor are not only faced with deciding between gasoline or electric power, but also diesel, diesel-electric, gasoline-electric or LP Gas. To compound the problem, a choice must be made concerning transmissions and fuels. This article lists what is available and the general characteristics of various truck and tractor drives. The advantages and disadvantages of each type of transport is discussed.

## METHODS IMPROVEMENT

"Planning and Controlling the Production of Transcribers", by Dr. O. R. Wessells, *Office Executive*, page 20, October 1955.

A case history describing how a methods analyst solved the problem of increasing clerical pool service by the use of unit times and a planning and control board. The installed system has proved a valuable aid to management. It has not only created individual and group interest but has made it easy to apply the principles of production management—job dispatching, individual and group evaluation, proper staffing, scheduling, etc.

## OPERATIONS RESEARCH

"Industrial Applications of Operations Research", by J. B. Lathrop, *Industrial Quality Control*, page 4, October 1955.

This article briefly outlines how operations research began, what it is and how it works, with some examples of its use. The author touches upon what it adds to present management techniques and some of the recent developments in the field. Examples discussed involve (1) Evaluation of a new development, (2) Production and inventory scheduling, (3) Planning machine runs, (4) Determination of production cost factors, and (5) Evaluation of advertising.

"QC Concepts Useful in OR", by P. S. Olmstead, *Industrial Quality Control*, page 11, October 1955.

The purpose of the article as stated by the author is to inform OR people about fundamental QC theory that should be useful in applying OR in other fields. The similarities between the two fields is that the aim of both is to establish an economic answer. In QC, it is reducing cost by eliminating assignable causes, usually in a single process; in OR it is comparison of the cost of several processes. Both, to be well done, require the cooperation of engineers and scientists alike.

## QUALITY CONTROL

"OR Concepts Useful in QC", by H. O. Davidson, *Industrial Quality Control*, page 10, October 1955.

The author proposes cementing the community of interests between the Operations Research and Quality Control fields by the addition of increasing numbers of Quality Control engineers to the Operations Research teams. The author proposes the two fields are similar in the following respects: (1) they are directed to (materially) useful objectives, (2) they deal with types of problems, which can be analytically generalized in working toward the objectives and (3) they have developed or adapted objective techniques for solving these problems.

## WORK MEASUREMENT

"A Survey of Time Study Policy and Practice in the United States and Canada", Society for the Advancement of Management (74 Fifth Avenue, New York 11, N.Y.) January, 1955. $1.50.

This report on a survey made by SAM covered 180 companies representing 17 different industry classifications. The survey found that the average time study man devotes 56.4 per cent of his activities to establishing work standards and 25.4 per cent to assisting in methods improvement. The rest of his time is spent on costing, production control, quality control and personnel work.

"Do It Now", by M. A. C. Hume, *Office Executive*, page 7, October 1955.

The author presents a potent case for a critical analytical review of existing office routines. Even with automation, this review is necessary in reducing and controlling clerical costs. He proposes that managements make the following decisions: (1) improve clerical work measurement; (2) improve or install work scheduling; (3) improve or provide written instruction; (4) eliminate the unnecessary; (5) seek fractional improvement as well as major ones; (6) strive for a cost-conscious attitude; (7) tap the latent ideas of the clerical workers; (8) strengthen clerical skills; (9) improve follow-up; and (10) make improvements now.

"Does Your Contract Permit Productivity", L. J. Haney, *Personnel*, page 71, July 1955.

Actual contract clauses relating to time study are quoted by the author. "Negotiating of standards is beset with traps for the unwary", the author states. Some of the major pitfalls and the steps taken to circumvent them are discussed. Six basic pointers are presented as a pattern for negotiation on productivity standards. For those in work measurement this would make very interesting reading.

"Rest Periods in Industry", R. M. Smith, *Personnel*, page 47, July 1955.

This article was written as a result of a survey made by the author. Of the 96 questionnaires sent out 50 were returned completed. Estimates of non-productive time from the various companies averaged approximately 60 minutes per shift. The author points out, however, that definite conclusions cannot be drawn since the estimates were not developed from independent studies. The overall allowances for both personal and operating delay factors were reported to be 11.7 per cent of the total working time.

## BOOKS

"Practical Plant Layout", by H. M. Somers and A. R. Somers; John Wiley and Sons, Inc., 440 4th Ave., New York 16, New York. 341 pages. $6.50.

This book describes the basic elements of good plant layout and includes specific procedures for the whole job of arranging work areas and equipment. The book has four basic parts—the fundamentals of the layout problem, how to collect the necessary data, how to plan the layout and how to install it.

"Employee Understanding and Team Work for Greater Productivity", by Prof. J. P. Troxell. National Association of Manufacturers, 2 E. 48th St., New York. 94 pages. $1.00.

This book was written after 2 years' research by the author on human problems in relation to productivity. The author explores the forces that tend to encourage good team work: sharing in the undertaking, participation in goal-setting and decision making, confidence in management's ability to organize and administer the business, and development of an understanding relationship among those who work together.

"The Impact of Computers on Office Management", American Management Association, 330 W. 42nd St., New York 36, New York. 60 pages. $1.75 ($1 to AMA Members).

A collection of papers given at the Office Management Conference of the AMA last October. The papers deal strictly with the application of computers to office and clerical jobs; however, some of the ideas may help in understanding the equipment and what it can do.

"Production Control Through Electronic Data Processing: A Case Study", by R. G. Canning. Office of Technical Services, U. S. Department of Commerce, Washington 25. 52 pages. $1.50.

No previous knowledge of electronic computers is needed to understand this report. The report considers some of the major principles involved in applying these new machines to business operations. To illustrate: it describes an in-plant research study, made at a medium size manufacturing plant and the electronic data processing system prepared to meet the production control requirement of the plant.

"Motion and Time Study", by B. W. Neibel, Richard D. Irwin, Inc., Howewood, Ill. 433 pages. $6.

This is a new text in fields of motion and time study, and wage payment. It covers methods now in use, describing and illustrating basic tools (operations analysis, process charts, micro- and Memo-motion study, etc.). Included are sections on work sampling, predetermined time systems, standards for indirect work and allowances.

## RESEARCH REPORTS FROM THE MANAGEMENT SCIENCES RESEARCH PROJECT, UNIVERSITY OF CALIFORNIA, LOS ANGELES

*These reports are not generally published but a limited number of copies may be obtained by writing to: Dr. Fred D. Rigby, Head of Logistics Branch, Office of Naval Research, Washington 25, D.C. Reproduction in whole or in part is permitted for any purpose of the United States Government.*

### Production Planning and Scheduling

No. 2. "An Evaluation of Current Quantitative Techniques in Plant Layout", J. R. Huffman, 19 pp.

An analysis of the quantitative techniques currently used for plant layout, with recommendations for a method of planning the flow of products in the plant.

No. 9. "On the Existence Problem of Linear Programming", J. R. Jackson, 9 pp.

A discussion and proof of the existence of a solution in linear programming.

No. 20. "Stochastic Search for the Maximum of a Function", E. W. Barankin, 18 pp.

A study of the stochastic convergence of a sequence of random variables conditioned by conditional probabilities. The problem is to find analytic conditions of the sequence of random variables which have large values for the conditional probabilities which will insure weak and strong stochastic convergence.

No. 22. "Production Rates and Inventories", T. Fabian and R. T. Nelson, 22 pp.

A model is developed for determining the constant rate of production which will maximize profit for a period of known demand, subject to a set of given assumptions.

No. 26. "Precedence Matrices", E. W. Barankin, 6 pp.

The main purpose of the analysis of precedence matrices is to devise a criterion for recognizing when a set of precedence relations $P$ is consistent; that is, one which has no mutually contradictory requirements. The scheduling or temporal ordering of items establishes a set of precedence requirements which may imply other precedence relations.

No. 28. "Job Shop Scheduling—An Application of Linear Programming", R. T. Nelson, 15 pp.

The factors which describe the difference between shop loading and scheduling are discussed. A small scale job shop scheduling problem is presented to illustrate a use of linear programming for industrial scheduling.

No. 31. "Detailed Scheduling of Industrial Production Activities", J. R. Jackson, 23 pp. (Revision of this paper in process—6/8/55.)

A mathematical model is used to represent the "job lot" scheduling problem. It considers the detail production schedule or "micro-programming" problem from an analytical point of view.

No. 32. "A Partial Ordering Determined by Certain Matrices", J. R. Jackson, 3 pp.

The paper characterizes a simple property of matrices from the point of a mathematical description of industrial production scheduling.

No. 33. "Exploding Manufacturing Outlines", J. R. Jackson, 5 pp.

A mathematical formulation of problems describing industrial or productive capacity. A given collection of information would constitute a description of plant capacity if one can determine whether long-term average production rates can be achieved.

No. 34. "Mathematical Methods in Management Programming", M. E. Salveson, 68 pp.

Consideration of methods such as linear programming for computing the most logical or efficient program in production control. It expresses profit for the firm in terms of a mathematical function. The computational method is discussed.

No. 35. "Notes on Some Scheduling Problems", J. R. Jackson, 7 pp.

A theorem is proved which generalizes the 2- and 3-machine scheduling problem solutions of S. M. Johnson, and is applied to several problems. In particular, the 2-machine problem is solved in the following cases: (1) possibly large, but not widely varying, transportation times are required for the job-lots between their processing by the first and the second machine; (2) the second machine may start processing a job-lot before the first machine has completed the entire lot; and (3) the setting up of the second machine for a given job-lot can start before the first machine has actually completed the lot.

No. 38. "Working Capital Model", P. Kircher and R. Rothschild, 14 pp.

Demonstration of the development and use of a working capital model, based upon scientific study of the relationship between the volume of sales and the size of individual working capital items. This paper proposes a method of planning expenditures under fluctuating sales conditions.

No. 41. "Various Optimizers for Single Stage Production", W. E. Smith, 9 pp.

This report develops theorems which enable one to schedule operations on a single-stage production system so as to minimize certain functions or optimizers. It is shown that the maximum tardiness of a job completion is minimized by ordering the jobs according to the date the job is due to be completed. The sum of times until each job is completed may be minimized under various conditions. If all jobs can be completed by their due-dates, a rule is given whereby a weighted sum of completion times can be minimized subject to all jobs being completed by their due-dates.

No. 42. "Toward Quadratic Programming", E. W. Barankin and R. Dorfman, 68 pp.

The problem is that of maximizing $g(x) = r(x) - s(x)$, where $r(x)$ is linear and $s(x)$ is positive semi-definite quadratic, over non-negative $n$-dimensional vectors $x$ satisfying given linear inequality constraints. Conditions are obtained that $g(x)$ be bounded above subject to the constraints; and it is shown that if $g(x)$ is bounded above, then the constrained

maximum is attained on a convex set, which reduces to a point when $s(x)$ is positive definite. The problem is transformed; and two algorithms for the transformed problem are proposed.

No. 43. "Scheduling a Production Line to Minimize Maximum Tardiness", J. R. Jackson.

Suppose a production-line must process a given bill of goods, made up of job-lots each of which requires a certain amount of the line's time. Further, suppose that tooling, raw material needs, etc., determine for each job-lot an earliest possible starting time, and that the completion of each lot is desired by some given due-time. This paper considers the problem of scheduling the required production in such a way as to minimize the maximum of the tardinesses of the items. Two cases are examined. In the first case, where the time required by any given job-lot can be split into several intervals if desired, the problem is solved completely. The second problem is that in which each job-lot must be assigned a single continuous interval. This problem is reduced to a finite problem which is examined in detail, a computing procedure being given whereby one can isolate a relatively small number of schedules which must include at least one solution. It is pointed out that the computing procedure can also be used to solve several related problems.

**Data Processing**

No. 16. "Electronic Data Processing Machine Requirements", R. G. Canning, 37 pp.

This report describes in more detail the electronic "computer" part of the production control system considered in RR 30, for the routine processing of clerical data. Major differences between this machine and today's mathematical machines are discussed.

No. 29. "Electronic Scheduling Machine Requirements", R. G. Canning, 42 pp.

This report describes machine requirements for the processing of a certain type of important repetitive management decision—the shop scheduling problem. It indicates how present day machines might be applied to this widespread production problem, and how specialized machines could be developed for more economical solution of the problem. The difference between a machine for routine data processing, and one for management decision-making assistance is described.

No. 30. "Production Control Through Electronic Data Processing: A Case Study", R. G. Canning, 53 pp.

This report, a consolidation of several previous reports, describes the production control problem present in many of the larger manufacturing plants, and the methods now in use under manual data processing systems. All of this information is presented in the language of the shop. Next, the general approach to electronic data processing is described, following which the details of an electronic system designed to meet the requirements of one local plant are outlined. Cost estimates and savings estimates are presented.

No. 39. "The Gap Between the Electronic Engineer and the Accountant", P. Kircher, 12 pp.

A careful study of a company's data processing needs and the capabilities of computing machines should accompany close cooperation between accountants and engineers. This paper investigates the reasons for this lack of cooperation and explains some of the major requirements of typical accounting systems in order to show the engineer some of the problems he must meet. It suggests programs of study to narrow the gap.

**Work Measurement**

No. 3. "Who Threw the Monkey-wrench in Mr. Tippett's Theory?" G. E. McAllister and R. T. Nelson, 9 pp.

A discussion of independence and recording of long delays in Ratio Delay or Work Sampling studies.

No. 11. "The Work Sampling Technique", A. J. Rowe, 14 pp.

A presentation of the theory and methodology in the application of sampling to the measurement of industrial activities, including work delays.

No. 12. "Random Ratio-Delay", G. E. McAllister, 9 pp.

The application of the statistical theory of random sampling to Ratio-Delay or Work Sampling. A description of how to design the sampling procedure, and analyze the results.

No. 24. "Relative Vs. Absolute Errors in Delay Measurement", A. J. Rowe, 8 pp.

A method is proposed for choosing an optimal sample size for work sampling. The method is a joint function of statistical theory and the accuracy of time standards.

No. 25. "Some Problems in the Application of Ratio-Delay Techniques", R. T. Nelson, 13 pp.

A discussion of some of the practical problems commonly encountered in the application of ratio delay or work sampling to various industrial situations.

No. 36. "A Statistical Model for Time Study", H. P. Edmundson and R. T. Nelson, 6 pp.

A discussion of the basic concepts underlying methodology and the proposal of a new statistical model as a sound basis for estimating standard time.

No. 40. "The Application of Allowances to Time Standards", A. J. Rowe, 4 pp.

The use of sampling has improved the estimates of allowances. Where allowances are not properly applied, they may lead to errors and inconsistencies. This paper discusses the possible errors and methods of correction.

## DISCUSSION PAPERS FROM THE MANAGEMENT SCIENCES RESEARCH PROJECT, UNIVERSITY OF CALIFORNIA, LOS ANGELES

*Distribution limited by authors. Persons who have permission to receive research reports may request discussion papers by writing to the individual authors. Discussion papers represent working reports and as such are distributed principally to stimulate ideas and, therefore, have limited distribution.*

No. 19. "Empirical Relationships for Measuring Worker Activity", A. J. Rowe, 18 pp.

This paper presents some tentative results from a pilot experiment conducted to determine whether the frequency distribution of working time was indicative of the effort or performance rate. A mathematical formulation relating skewness and the rate of activity is presented.

No. 21. "A Linear Programming as a Tool for Industrial Scheduling—I", R. J. Jackson, 15 pp.

This paper together with Discussion Paper 26 outlines a way in which linear programming might be used to distribute the machine load of a job shop over several intervals of time, in such a way as to minimize or maximize some objective function. The technological requirements on the order in which various things are done are taken into account, and devices for including various special possibilities are described. It is pointed out that the model will generally be too large for direct application.

No. 26. "Linear Programming as a Tool for Industrial Machine Loading—II", J. R. Jackson, 11 pp.

See Discussion Paper 21.

No. 33. "Electronic Computers and Accounting", P. Kircher, 12 pp.

The potential uses of electronic computers in accounting are now becoming rather generally known. A considerable change apparently is becoming in two interdependent areas: (1) Normal record keeping. (2) Provision of special data for decision making purposes. This paper reports the results of studies of potential use of the computers in each of these areas. They are based on investigations of two specific problems.

No. 34. "Early—Punctual—Late", H. P. Edmundson and G. E. McAllister, 4 pp.

As a first step in a stochastic generalization of the deterministic completion times of commodities in the Salveson Scheduling Model, this paper considers that the performance times define a sequence of chance variables. These chance variables form a discrete markov chain with precisely three states—early, punctual, and late.

No. 48. "An Analysis of the Applicability of Standard Data for Production Scheduling", A. J. Rowe, 10 pp.

The basic premises associated with standard data are analyzed to determine whether these considerations are important for production scheduling. The questions considered include the dependence of motion sequence and motion classification. It is shown that the expected value of a sequence of motions whose time values are random variables can be determined even where there is statistical dependence.

No. 50. "Enumeration of a Three Job, Three Machine Scheduling Problem on SWAC", R. T. Nelson, 10 pp.

It is assumed that three job-lots must be scheduled through three machines, each requiring a single interval of a certain length of each machine's time. A "technological ordering" is a specification of the order in which the three machines must process each item. A "schedule" is a specification of the order in which the items will be processed by each machine. The paper summarizes a SWAC enumeration, which determined which schedules were feasible in conjunction with the various technological orderings in the sense of involving no contradictions, and which need be considered in seeking a schedule to minimize over-all time.

No. 51. "Priority Function Methods for Job-Lot Scheduling", R. T. Nelson, 34 pp.

This paper summarizes preliminary ideas on shop-scheduling by the use of simple "priority-functions" which decide which of several available job-lots to process next, when a machine becomes available. It also gives the results a few small-scale simulated applications of the methods discussed.

No. 52. "Research Problems in Production Routing and Scheduling", A. J. Rowe.

This paper is concerned with a discussion of the basic problems in production routing and scheduling. It proposes an integrated approach to lot size, routing and scheduling as the basis for an optimum solution to the problem. Problems still requiring research are indicated and possible methods of solution are proposed.

# INSTITUTE INTERESTS

## REPORT ON NATIONAL CONVENTION—ST. LOUIS

In many cases the growth of a professional engineering organization can be measured by the stature and nature of its annual conference and convention. The American Institute of Industrial Engineers has completed its sixth annual conference and convention which was held in St. Louis on 12, 13 and 14 May, 1955. From all indications (financial success, attendance, good comments from attendees, program stature, etc.) this conference and convention was the most successful one ever held by AIIE. Our organization is close to maturity, and our future conferences have a new high standard to meet.

In establishing the basic concepts for the Sixth Annual Conference and Convention, the Convention Committee felt that our annual national conventions should accomplish certain specific objectives. These are: to provide a national forum for the interchange of technical information; to provide an opportunity to meet others in similar work throughout the country; and to provide another medium through which the collective activity of the society can be made known to the public at large.

To accomplish these objectives, the Convention Committee offered a technical program to attract the largest possible number of Industrial Engineers. Also offered was a pleasant social atmosphere wherein old acquaintances could be renewed and new friendships established. The public at large and as many Industrial Engineers as possible were made aware of the conference and its program. Lastly, properly recorded results of these activities were made available.

This report serves as a review of the conference in the light of these objectives. To attract as much interest as possible, a program of sixteen technical sessions was developed. The program was arranged with two concurrent sessions so that a choice was available for each of eight scheduled meetings over the two-day period. The subject material was arranged so that topics in the same general area occurred at different times and in different combinations so that a broad area of interest could be covered without missing all sessions on any one subject.

The basic theme of the Conference, "A Panorama of Industrial Engineering: The Latest in Techniques", indicated the objective of the Convention Committee in the nature of the program.

The areas covered included material handling, time study, investment, automation, control charts, job evaluation, basic research, statistics, operations research, industrial relations, and work simplification. These topics were presented by capable speakers from the United States and Canada. California and Massachusetts provided speaker representation, as did New York, Michigan, Kentucky and other states. Specific highlights of the program included luncheon speakers of particular renown. No comment is necessary on the place that the banquet speaker, Dr. Lillian Gilbreth, holds in the industrial engineering world, as well as in many other areas of human activity.

To publicize this program, 15,000 copies of the pre-convention flyer were distributed throughout the nation. One month prior to

the convention 25,000 final program brochures were also mailed. Notices were sent to a great many newspapers and trade periodicals. The week of May 9th to May 14, 1955 was proclaimed "Industrial Engineering Week" in St. Louis by the Mayor of the City of St. Louis.

Immediately prior to the convention, an informal gathering was arranged at "Grant's Farm," the historic estate of the August A. Busch family. This reception was held the afternoon prior to the start of the technical meetings and provided an excellent opportunity for those attending to spend a social afternoon in unusually pleasant surroundings. An opportunity was afforded for informal gatherings in the Exhibit Hall and in various committee rooms during the Conference and Convention.

It was felt that industrial exhibits by suppliers of tools, methods, and equipment can be useful in providing industrial engineers with an opportunity to become acquainted with the latest information. It will also provide suppliers of such equipment and services with the opportunity to contact the industrial engineering group as a whole to present their ideas and developments. Some of the exhibits of material handling equipment and methods control equipment proved very interesting. Several exhibitors have already requested information on the next conference so that they may participate again. This program will grow and industrial exhibits will be a very interesting and inportant part of the AIIE National Conference.

Over 450 people attended the Conference and Convention. These people represented practically every industry and field of industrial engineering. They came from throughout the United States and Canada. Management and union groups were both represented. Some international flavor was added by the attendance of an exchange professor from Korea. A total of over 1000 meals were served at the two luncheons and banquet during the Conferences.

To provide a permanent record of the technical work accomplished, a *Conference Proceedings* was published. This book was available at the Conference and proved of great interest. Comments were received on the value of such a publication in assisting conference attendees in reviewing while the material presented by the speaker was fresh in mind. It was also of assistance in determining which session would be most interesting to the individual industrial engineer. Some copies of the Proceedings are still available at National Headquarters.

The spirit of the conference was demonstrated by the number and type of auxiliary meetings held during the three days. This type of meeting demonstrates one of the important ways ideas and professional growth are aided. There were committee meetings on various subjects related to the organization of AIIE and in relation to professional topics and stature of Industrial Engineering. In addition, a special meeting was organized by D. G. Malcolm to discuss the general concept and problems of Industrial Engineering as a whole. This meeting was attended by such outstanding Industrial Engineers as Lillian Gilbreth, R. Conrad Cooper, Ralph Barnes, C. W. Lake, E. L. Slagle, C. V. Gustav and others from industry and universities.

The Conference and Convention cost a total of over $8,400.00. A large part of this money was spent on publicity. Meals and hotel facilities required several thousand dollars. Printing was an expensive item. A multitude of miscellaneous items necessitated a large total expenditure. Those on the Convention Committee learned very quickly that a National Convention is big business.

In spite of the care taken on each of the many, many details that had to be considered, this conference, as do all others, had its own "slip". Our speakers' badges were spelled "Speaer." Although the Convention Committee was thoroughly mortified when the mistake was discovered, it was amazing that more people did not notice it.

To sum up the overall results of the General Committee's work, a book was prepared containing eleven sections and over seventy pages. This described in detail the work of each committee in preparing for this Conference and Convention. These reports have been submitted to the National Headquarters and to future National and Regional Conference Committees for what assistance they may be. Through these detailed reports, it is hoped that the mistakes that may have been made in St. Louis may not be repeated elsewhere, and that any important techniques we may have learned will also be available.

Perhaps the most important figure in the final convention report is one labelled "Distribution of Net Favorable Balance to National AIIE—$2,394.28".

The Convention Committee Chairmen feel that any success this Conference and Convention may have enjoyed is due to the earnest and wholehearted efforts put forth by the Functional Committee Chairmen and the Committee Members of the St. Louis Chapter, American Institute of Industrial Engineers. The Committee Chairmen who contributed so much are:

| | |
|---|---|
| George Ferguson | Owen W. Miller |
| E. K. Gavin | W. R. Overbey |
| Charles Geisel | Victor J. Tilly |
| Harry Kelly | A. C. Zunzer |

George T. Wanninger

This was a truly cooperative venture and represents the finest efforts of a great many fine people.

(Signed)
JOSEPH MOVSHIN
GERALD NADLER
*Conference and Convention Cochairmen*
St. Louis Chapter

## KNOXVILLE CHAPTER

A Memphis co-ed about to add her talents to the shortage-ridden engineering field has been singled out by her all-male classmates and faculty members at the University of Tennessee as U-T's outstanding industrial engineering senior.

Scheduled to receive her engineering degree in December, Miss Pat Wintker was honored on October 21st as the first co-ed winner of the annual award given by the East Tennessee professional chapter, American Institute of Industrial Engineers. M. B. Beverly, AIIE liaison officer, presented the award.

Though engineering educators have been promoting for some time the idea of women in engineering as one means of alleviating the shortage, Miss Wintker's debut at Knoxville four years ago created something of a stir. There had been only about three co-ed graduates of this college and it was thought that maybe they were "exceptions".

The 22-year-old Pat is an "exception", too, according to Prof. Howard P. Emerson, Head of the Industrial Engineering Department, but not simply because she's a co-ed.

She has been president of the student chapter of AIIE, editor of "The Tennessee Engineer", a member of the board of the all-engineering student governing association, and an officer of the honorary industrial engineering society, he said. She has held two scholarships, one given by Sears and one by General Electric.

Participating in the ceremonies were H. P. Hassell, President of the Knoxville Chapter, and Professor H. P. Emerson, Head of the University of Tennessee's Industrial Engineering Department.

## LOUISVILLE CHAPTER

The Louisville Chapter launched its 1955–56 program at the September meeting with a lucid explanation of "Linear Programming", minus all reference to higher mathematics. The speaker, Mr. T T. Kwo from the Digital Computing Center of General Electric's Appliance Park, handled his topic with perception and humor. The effects of a recent innovation by the new president were already in evidence at this meeting. The new system, under

which each officer and committee member received a written list of tasks and functions, promises to eliminate some of the confusion that has existed in the past with regard to overlapping committee assignments.

The October meeting of the Louisville Chapter was held at the Mayflower Hotel on October 19th. Mr. John C. McKenzie of IBM spoke on "Punched Cards and the Industrial Engineer." Mr. McKenzie graduated from V.M.I. and joined the IBM organization in July 1938. In 1946 he was advanced to the Sales Department in which he has held various positions. In July 1953 he was assigned to the Louisville office and is now making a specialty of Electronic Data Processing Equipment.

The Louisville Engineering and Scientific Societies' Council (the Louisville Chapter of AIIE is a member society) sponsored the Louisville appearance of an exhibit entitled "Civilization Through Tools", a presentation of the Do-ALL Company of Des Plaines, Illinois. This exhibit, with accompanying lecture, dealt with the development of man's tools through successive stages of his existence. The company sent out some 3,000 invitations to the exhibition, which was open to the public. The exhibit was presented at 8:00 P.M. on Monday, December 5, at the Speed Scientific School Auditorium, University of Louisville.

## BIRMINGHAM CHAPTER

Operations Research fills a need of the professional managers of today, but some of its proponents tend to deal more in techniques than in concepts, according to Edwin M. Bartee of Bruce Payne & Associates, Inc., Management Consultants. Mr. Bartee, speaking to a Birmingham meeting of the American Institute of Industrial Engineers, said that Operations Research is fundamentally a combination of Taylor's concept of scientific management and Fisher's work on statistical methods.

"Today's executives can't afford to make many mistakes," said Mr. Bartee, "and Operations Research helps management to make decisions with less chance for error."

Showing the importance of both careful sampling and the separation of unexpected variations from expected ones, Mr. Bartee said that management by exception was a good practice only if the causes of exceptionally good performance were given as much attention as troubleshooting.

Mr. Bartee concluded by saying that the continuing industrial revolution that we are now witnessing can be paralleled by a mental revolution—the use of factual data supplied by Operations Research instead of opinion as a basis for management decisions.

Mr. Bartee, a native of Sylacauga, Alabama, is a graduate of the University of Alabama with a Bachelor of Science and Master of Science degrees in Industrial Engineering. He also studied engineering at Birmingham Southern College and the University of New Hampshire. Mr. Bartee is a member of the American Institute of Industrial Engineers, and the Society for Advancement of Management.

## METROPOLITAN NEW YORK CHAPTER

On November 5th, sixty members and friends of the Metropolitan New York Chapter visited the Brookhaven National Laboratories for the chapter's Fall inspection trip. Although the ride to Upton, Long Island was wet and windy, the inconveniences were more than made up for by an extremely interesting tour of the Laboratory's facilities.

The first step on the tour was the registration desk, where each visitor was given a combination film badge-identification card. The film was radiation-sensitive and was later developed to indicate the amount of radiation each person was exposed to. Following registration, a talk was delivered on the purposes and organization of the Brookhaven National Laboratories. Among the interesting facts learned at this point were the following: the laboratories are located on the site of what was formerly Camp Upton (of World War I and II fame); the laboratories are operated for the Atomic Energy Commission by Associated Universities, Inc., a private organization composed of nine sponsoring universities; the laboratories' monthly electric bill runs to approximately $45,000; and, out of about 1500 people employed there, about 300 are Ph.D.'s.

One of the thorniest problems confronting this unique installation is that of waste disposal. Radioactive wastes cannot be disposed of in the usual manner . . . and the waste volume runs to hundreds of thousands of gallons monthly. One example of the measures taken to eliminate the dangers of radioactive waste is the 410-ft. tower used to dispose of "hot" gases. Rigid tolerances are maintained on the exposure of personnel to radiation, to the extent of having a team of health physicists on hand whenever work is done in the presence of radiocativity.

The introductory talk was followed by a tour of the machine shop, where parts and equipment are fabricated for the various research projects. The next stop was the nuclear reactor, or atomic pile. This reactor is a massive cube containing tons of graphite and uranium encased in a heavy concrete shield. All six sides of the cube contain openings through which experiments are simultaneously conducted.

The "hot" chemistry lab next revealed research projects being conducted with radioisotopes. Some of these were: tracing and process control; general-purpose radiography; measurement and control of flow; gaging and controlling thickness of continuous sheet materials; control of coating thickness; conducting superfast and superaccurate analyses; and treatment of brain cancer.

The final leg of the tour was devoted to the cosmotron, a doughnut-shaped electromagnet 75 feet in diameter. The cosmotron propels protons around a circular orbit, raising them to an energy level of three billion electron volts. Now under construction is a synchrotron 750 feet in diameter capable of accelerating protons to energies of 25 billion electron volts. The synchrotron will cost in the neighborhood of $25,000,000.

This inspection trip was one of two planned by the Metropolitan New York Chapter for the 1955–56 season. It was interesting and thought-provoking; when you get that close to the world of the atom, you can't help wondering what all this will mean to us and our children in years to come.

## SOUTHERN TIER SECTION

The recently chartered Southern Tier Section of AIIE experienced a notable and unforgettable occasion in its October Meeting. It initiated the first Industrial Engineering Clinic, sponsored jointly by the Section and the I.E. Department of Cornell University at Ithaca, New York. Professor Harry J. Loberg, Director of Sibley School of Engineering, and Professors Andrew Schultz and Byron W. Saunders assisted in arrangements.

An all-day clinic in Statler Hall provided an opportunity for twenty-seven members and guests, representing six area industries, to review techniques in Work Sampling Methods and Linear Programming. Professors Martin W. Sampson, Robert E. Bechhofer of the Cornell Staff and Mr. John Allderige of Eastman Kodak Company, Rochester, directed the Work Sampling group. Professors Byron W. Saunders, Robert E. McGarran and Eugene Richman of Cornell conducted Linear Programming.

Following the session, members were invited to see a demonstration of complete automation in Thurston Hall. The machine is being developed for printed circuit panels. Component assembly may be changed as desired by use of punched card programming.

The clinic was concluded with a banquet in Statler Hall. About seventy attended including a distinguished group with E. L. Slagle, National President of AIIE and National Past Presidents Donald G. Malcom, F. F. Groseclose and M. A. Payne.

President Slagle introduced Donald Malcom who presented the address—"The New Industrial Engineering". Mr. Malcom built his subject around the modern definition of Industrial Engineering

formulated at a symposium of Industrial Engineers which convened concurrently with the clinic.

President Slagle predicted that Industrial Engineers, as a group, must look to their own future, to their Code of Ethics and see that it is a job well done. They must *earn* a higher level of respect if they expect to receive it from others. Industrial Engineers hold their place today because they meet some definite need of Management.

Mr. Malcom stressed that we live in an era where technological change comes at an ever increasing rate, causing serious shifts in the concept of Industrial Engineering. As a result, we must view the character of the Industrial Engineer in a new perspective as it emerges from these changes. Thus, we must keep alive to progress and familiar with the advance of new techniques. At the same time, it will be necessary to keep expounding what an Industrial Engineer does and to evaluate the personnel to determine fairly if one is really doing the job of an Industrial Engineer.

The Southern Tier Section meets on the third Thursday at 7:00 P.M. at the Iron Kettle Inn, Waverly, New York.

### DAYTON CHAPTER

A meeting of the Dayton Chapter was held on Tuesday, November 1, 1955 at 8:00 P.M. in the Standard Register Auditorium, Albany and Campbell Streets. The speaker was Harry Mayfield, President of the Columbus C.I.O. Council and Area Director of United Steel Workers of America, District 27. His subject was "Trade Union Viewpoint of Job Evaluation." Mr. Mayfield has been with the United Steel Workers since 1939 and has engaged in organizational as well as servicing work.

Mr. Louis Polk, President of the Sheffield Corporation, will address a joint meeting of all DATEC Societies later in November. His topic will be "Industrial Conditions in Foreign Countries."

Dr. Abraham Charnes, Professor of Mathematics at Purdue University, will speak on "Linear Programming" at the December meeting. Dr. Charnes played an important part in the early theoretical development of the subject.

### JACKSONVILLE CHAPTER

The Jacksonville Chapter held its regular monthly meeting Thursday, October 13, 1955, at the Mayflower Hotel. There were present 19 members of the AIIE, plus two student members from the University of Florida at Gainesville and four guests. The speaker of the evening was Mr. Robert A. Martin, District Manager of the Liberty Mutual Insurance Company, Jacksonville, Florida. Mr. Martin gave an outstanding discussion on the subject "Workmen's Compensation Insurance."

### ST. LOUIS CHAPTER

The October meeting of the Chapter was held on October 12 at the Bismark Cafe. The speaker was Dr. L. W. Wallace, Conference Leader Top Management Seminar, Ordnance Management Engineering Training Program, Rock Island Arsenal, Rock Island, Illinois. His subject was "Functions of Management." Dr. Wallace is one of the pioneers in the Industrial Engineering field. He has been in Engineering, Management and Research positions in some of our largest companies, government agencies, and international conferences. He holds important positions in many Engineering societies, is listed in several Who's Who publications, and his list of honors would fill this page. He has taught in many large universities and is at present in charge of a course to teach Industrial Engineering techniques to government workers.

### SYRACUSE CHAPTER

The first meeting of the current season of the Syracuse Chapter of AIIE took place on Tuesday, September 13th, at the Corinthian Club, James Street, Syracuse, N. Y.

An excellent dinner at 7:00 o'clock was followed by a very brief business meeting, Mr. O. Manse, Chairman. The speaker of the evening was introduced by Mr. Gwynn Thomas of The Manufacturers' Association of Syracuse. The speaker, Mr. John Schenck, President of Engelburg Huller Company, Syracuse, and Director of MAS gave a brief outline of MAS–AIIE relationships and presented an analysis of the industrial outlook for the Syracuse area. Mr. Schenck's talk was followed by a very lively, general discussion period.

The second meeting was held at the same locale on Tuesday, October 4th. Dinner was again at 7:00 o'clock. No business was conducted, but several announcements were made by Mr. O. Manse as Chairman of the Executive Committee.

The speaker of the evening was Dr. W. R. G. Baker, Vice President and General Manager, General Electric Company, Syracuse, N. Y., whose subject was "Automation." He was introduced by Mr. E. Parker, Past President, Syracuse Chapter AIIE. Following Mr. Baker's talk we enjoyed an excellent discussion period on the topic and related problems.

Monthly meetings are to be held at the Corinthian Club, 930 James Street, Syracuse, New York. Telephone: 74-3328. Dinner and Cocktails: 6:30 P.M. Business Meeting: 8:00 P.M.

### WINSTON-SALEM CHAPTER

The Winston-Salem Chapter began its fourth year of activities with a membership of 51.

At the September meeting, Mr. Alvin Page, Chief Engineer of the Bahnson Company spoke on "State Registration for Engineers." Mr. Page informed the chapter and guests of the procedure and advantage of becoming registered as a Professional Engineer. Information concerning the time and place of the examinations may be obtained by contacting Professor R. B. Rice, N. C. State College, Raleigh, N. C.

Mr. Stephen A. Derry, an associate of Derry Engineers, Louisville, Kentucky, spoke at the October meeting on the subject "Automation." He covered the subject from the overall viewpoint, including what it is, what it does, its history, its initial cost, the attitude of labor, and related items. A movie depicting the installation and operation of automation in a foam rubber plant was shown.

The "Time and Motion Study Conference," which is sponsored annually as a joint effort of the Greensboro Area Chapter, S. A. M., and the Winston-Salem, AIIE, will be held in Winston-Salem on January 19 and 20.

### CLEVELAND CHAPTER

The first meeting of the year was held on October 6 at the Hotel Cleveland. The guest speaker was Mr. James M. Osborne of Ford Motor Company who covered one of the most talked about subjects of this day: "Guaranteed Annual Wage", or better known by the Ford Company as the "Ford Supplemental Unemployment Benefit Plan." Mr. Osborne is Supervisor of Industrial Relations Survey and Research of Ford Motor Company and was a member of the company team which negotiated the new contract between Ford and the UAW-CIO.

A Television Committee has been formed for the purpose of presenting TV programs which will establish the Industrial Engineering section of Engineering as a profession in the minds of the public, and to explain the opportunities in that field. These television shows are a part of an Engineering Program sponsored by the Cleveland Technical Societies Council. It is planned to have two shows this year; one will be in the fall and the other in the spring of 1956.

An Exhibit Committee has been formed which will function for the first time this year. The purpose of the committee is to provide at each Chapter Meeting an opportunity for members to see what other Industrial Engineers are doing in the field of Industrial Engineering and to exchange ideas.

Three or four exhibits will be put on by Industrial Engineering

groups to display techniques in Plant Layout, Time Study, Wage Incentive Systems, Ratio Delay Studies, Suggestion Systems, Budgetary Controls, Cost and Statistical Analysis, etc.

The displays will be explained and discussed during the social period by the Chapter Members from companies or consulting groups presenting the display. Each company and consulting group will have an opportunity to submit a display during the year. It is felt that the opportunity to exchange and obtain new ideas will provide another service to make Chapter meetings more constructive and worthwhile.

### TULSA CHAPTER

This past spring the Tulsa Chapter inaugurated an award to be given each year to an outstanding graduating industrial engineer at Oklahoma A. and M. College. The honor this year was presented to Richard Wolfe, of Chicago, at the Oklahoma Institute of Technology Honors Day program in May. Mr. Wolfe was selected by a committee of AIIE Student Chapter members and I.E. faculty members. He was selected because he has the personal qualities that most nearly suit the three points that are the basis of the award. These are:

1. High scholastic achievement
2. Exceptional leadership ability
3. Efforts to improve his profession by service to the student AIIE Chapter

In addition, the winner each year must be a member of the Student Chapter at Oklahoma A. and M.

As will all future winners, Mr. Wolfe received a certificate, AIIE membership fees paid for one year, and an AIIE lapel pin. A plaque will be given the School of Industrial Engineering at O.I.T. It will have the winner's name inscribed on it each year.

In establishing this annual award, the Tulsa Chapter seeks to accomplish several things: recognition of an individual I.E. for a noteworthy college career; recognition for the Student Chapter on the campus; and a feeling of mutual interest and aid between The Tulsa Chapter and the Oklahoma A. and M. Student Chapter.

### ATLANTA CHAPTER

Paul J. Brown, Jr., Director of Production at Scripto, Inc., was the speaker at the first monthly meeting of 1955–56 of the Atlanta Chapter on Tuesday evening, September 27, at the Town House.

The title of the talk was "Methods in Action." Mr. Brown discussed the various industrial engineering principles applied by him and his associates to obtain efficient and maximum production at the lowest possible cost.

A native of Albany, Georgia, Mr. Brown obtained a degree in industrial engineering from Yale University in 1936 and joined the staff of Scripto, Inc., being appointed to his present position in 1947. During World War II he served as an Army officer with the First Armored Division and Army Service Forces. In 1954 Mr. Brown completed the Harvard University Advanced Management Program.

### BATON ROUGE CHAPTER

The Baton Rouge, Louisiana Chapter is off to a fine start!

The first meeting of the new year was held on September 26, 1955 at the Broadmoor Steak House.

Dr. Fred H. Fenn, Director of University College, Louisiana State University, gave a short talk on "University and Adult Education". His presentation was very enlightening and it was quite surprising to learn the number of people attending night classes.

The main speaker of the evening was Mr. G. R. Lipscomb, the New Orleans District Manager of the Standard Register Company.

He presented an interesting discussion on "Simple Facts of Integrated Data Processing". His talk and the slides he presented showed how office and shop procedures can be stepped up through the use of modern machine methods.

We consider ourselves quite fortunate in having had as our guest speaker at our October meeting Mr. E. L. "Ed" Slagle, our National President.

Ed's topic of discussion was "The Industrial Engineer's Share of The Total Management Function". In his talk he gave a most complete and informative outline of the areas of Industrial Engineering responsibility.

His broad presentation was quite well received by the non-engineer guests attending the meeting. These guests represented management positions of local industries, newspaper, university, and city-parish government.

Ed pointed out that the Industrial Engineer must be recognized as a chief function of the company and must be approved and backed by top management. However, the Industrial Engineer must also realize and understand that he is acting as Management's conscience and that his function is that of a service. He must be willing to accept the idea that he merely makes the determination of the facts for others to follow and apply.

During his visit, Ed toured some of the local industries and the Louisiana State University School of Engineering.

We would all like to congratulate our Program Committee for doing a fine job.

## BOARD OF TRUSTEES' MEETING

### Columbus, Ohio

### October 22, 1955

*The Board of Trustees of AIIE is the official governing body of your organization. This group meets to conduct business for you twice a year. The official minutes of the October Board of Trustees' meeting are published in the Journal to keep you informed of AIIE activity.*

President E. L. Slagle called the meeting to order at 9:00 A.M. The following members of the Board were in attendance:

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|---|---|
| E. L. Slagle | President |
| Col. William N. Egan | N.E. Region Vice President |
| John M. Farnbacher | Central Region Vice President |
| Gerald Nadler | N.W. Region Vice President |
| Frederick D. Macy | S.W. Region Vice President |
| W. Grant Ireson | West Region Vice President |
| Frank T. Geyer | Treasurer |
| J. L. Southern | Executive Secretary |
| Stephen D. Veirs | Assistant Executive Secretary |
| F. F. Groseclose | Board Member-at-large |
| Alex W. Rathe | Board Member-at-large |
| D. G. Malcolm | Board Member-at-large |

Other than Board Members in attendance:

| | |
|---|---|
| Ralph O. Swalm | Director of Programs |
| Don A. Trenwith | Business Administrator, Nat'l Hdq. |

President Slagle read a telegram from Kyle Reed, Board Member-at-large, expressing his regret that he was unable to attend the meeting. Also, in Dr. Reed's telegram, he asked that John Farnbacher act as his proxy.

*Minutes of May 13, 1955, Board of Trustees Meeting.* Dr. Rathe moved that we adopt the May 13 Board of Trustees Meeting Minutes as written. Seconded by Colonel Groseclose and motion carried.

### UNFINISHED BUSINESS

*Election of Officers.* Dr. Rathe moved to present to the membership the recommendation of changing Article VII, Section 10 of the Constitution to read as follows:

"All officers except board members-at-large shall have terms of office of one year. Board members-at-large shall serve three years with staggered terms."

Seconded by Mr. Southern. Motion carried.

Mr. Malcolm moved that in implementing this, if voted upon favorably by the membership, that the Election of Officers Ballot be marked for three new board members, one for a one-year period, one for a two-year period and one for a three-year period. Seconded by Colonel Egan. Motion carried.

Dr. Rathe moved to submit a recommendation to the membership to change Article VII, Section 12 of the Constitution to read as follows:

"A slate of officers, excluding the offices of regional Vice Presidents, Executive Secretary and Assistant Executive Secretary, shall be drawn up yearly by a nominating committee consisting of the last three past presidents and the current president, with the oldest one in point of service acting as chairman. Each regional Vice President shall submit to the nominating committee two names for each office of the slate for consideration in arriving at one nominee for each office. By petition delivered to the Executive Secretary at least four weeks prior to the mailing of ballots to the membership and containing the signatures of at least fifty members, additional candidates may be added to the ballot. Officers shall be elected, by mail vote of the entire regular membership. Ballots will be distributed by the Executive Secretary and will be counted by the Executive Secretary and a Tellers Committee appointed by the President." Second by Colonel Groseclose.

After much discussion and failure to reach a deciding vote on the motion; Dr. Nadler moved to table the above motion regarding Article VII, Section 12 and that the matter be given to the Constitution Committee to investigate what other societies do; and, also, what the pattern of result of other engineering societies is. Mr. Farnbacher seconded the motion. Motion carried.

Dr. Rathe moved that the board recommend to the membership a change in the Constitution concerning the composition of the nominating committee to be as follows:

"The nominating committee consist of the immediate past three presidents and the current president."

Mr. Macy seconded the motion. Motion carried.

Mr. Malcolm moved that the Constitution and By-Laws as printed and revised September 10, 1955 be the official Constitution and By-Laws of the Institute. Mr. Macy seconded. Motion carried.

Mr. Southern brought up the point that the Board of Trustees at their meeting on May 13, 1955 had referred Article IV, Section 2 of the By-Laws to the incoming Board for clarification.

Colonel Groseclose then moved that we add to Article IV, Section 2 of the By-Laws an "s" to the word "meeting" where it appears the second time; thus, making Article IV, Section 2 read as follows:

"The Board shall hold at least one meeting a year, the expense of such meetings may be paid from the funds of the National Treasury."

Seconded by Mr. Macy. Motion carried.

Mr. Malcolm moved that Article V, Section 4 and the words that are written in the May 13, 1955 Board of Trustees Meeting minutes with any amendments that were made subsequent be adopted. Mr. Southern seconded. Motion did not pass. Three in favor and 9 opposed.

Mr. Southern read a letter dated April 13, 1955 from Dr. Rathe regarding consideration for a Fellow membership. The Board decided to refer this to the next Executive Committee Meeting to make recommendation to the May, 1956 Board of Trustees Meeting.

**NEW BUSINESS**

*Treasurer's Report.* Mr. Geyer reported that we now have a Journal and Ledger System and that the new bookkeeping system is progressing steadily.

The new balance sheet and statement of operations were distributed to the Board. The Board decided to eliminate the "May 1, 1955 to August 31, 1955" column and to add the column "Budget to Date."

Mr. Farnbacher moved acceptance of this new form as modified. Seconded by Mr. Malcolm. Motion carried.

Mr. Southern moved to amend Article V, Section 1 of the By-Laws to change the fiscal year to May 1 through April 30. No second.

The Board showed an expression of sincere thanks to Mr. Geyer for his establishment and completion of the new accounting system.

*Secretary's Report.* Recent Constitution Changes—Mr. Southern distributed to the Board the attached tally sheet[1] showing that the Constitution changes had passed. Mr. Southern reported that the total number of votes cast by the membership were 393.

*Chapter Boundaries.* Mr. Southern reported that the Chapter boundaries had been established. If any chapters wish changes in their boundaries they may request such by writing to the Executive Secretary. All adjustments will be made July 31, 1956.

Mr. Malcolm moved that the Article I, Section 3 of the Constitution be referred to the Constitution Committee for re-examination and re-statement in line with present chapter boundaries and dues collection policy. Mr. Geyer seconded the motion. Motion carried.

*Dues Billing.* Mr. Southern displayed a work sheet and a to-date record and breakdown of receipts; these were distributed to the Board for their information.

*Luncheon Recess.* 1:00 P.M.—Meeting reconvened at 2:10 P.M.

*Report of Long-Range Planning Committee.* Mr. Malcolm reported that the meeting of the Long-Range Planning Committee held October 20 and 21 in Ithaca, New York had been a great success.

Mr. Malcolm reported the following definition of Industrial Engineering was established at that meeting:

"Industrial Engineering is concerned with the design, improvement and installation of integrated systems of men, materials and equipment; drawing upon specialized knowledge and skills in the mathematical, physical, social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems."

Colonel Groseclose moved that we accept this definition as presented for purposes of the Industrial Engineering Opportunities Brochure. Seconded by Dr. Nadler. Motion carried.

Dr. Nadler moved that the Long-Range Planning Committee and the group of men participating in the definition of Industrial Engineering for the brochure be formally commended. Seconded by Mr. Farnbacher. Motion carried.

*Dues.* President Slagle proposed the following changes in dues rates:

| | |
|---|---|
| Senior | from $12.50 to $17.50 |
| Associate | from 7.00 to 10.00 |
| Affiliate | from 7.00 to 17.50 |

Dr. Nadler suggested that serious consideration be given to any possible elimination of the two chapter dues rates. In considering changes in the dues structure.

Dr. Rathe moved that By-Laws, Article V, Section 4 be amended to read as follows:

"National dues shall be as follows: Student Members, two dollars; Affiliates, seventeen and one-half dollars; Associate Members, ten dollars; Senior Members, seventeen and one-half dollars. After five years in the Associate classification, members shall pay dues at the Senior rate."

Motion seconded by Dr. Nadler. After considerable discussion the motion carried with one (Mr. Macy) against.

The President has stated that he will, as soon as possible, get a letter to all members stating the reasons for the dues increase and the results that will come from this increase. President

[1] Tally sheet not reprinted. Copies can be obtained from Headquarters. (Ed.)

Slagle further urged all Regional Vice Presidents to contact all chapter officers explaining in their own words the reasons for the dues increase and what they can expect from this increase.

Mr. Veirs moved that the effective date of the new dues rate be January 1, 1956. Mr. Southern seconded. Motion carried. Mr. Macy abstained.

*Fees.* Mr. Veirs moved that the application fee be increased from $2 to $5, the $5 to be refundable. Mr. Farnbacher seconded the motion. Motion did not carry for lack of a three-fourths majority. Six votes in favor and five opposed with Mr. Southern abstaining.

Dr. Rathe moved that the application fee be increased to $7 to be refundable. Motion seconded by Dr. Nadler. Motion not passed for lack of three-fourths majority.

Mr. Farnbacher moved to increase the application fee to $5. No second.

Dr. Rathe moved to increase the application fee to $6 to be non-refundable. No second.

Mr. Veirs moved that the application fee be increased to $5. Mr. Southern seconded the motion and motion carried with nine in favor.

Mr. Veirs moved that the $5 application fee be refundable. Seconded by Mr. Macy and motion carried with eight in favor. Mr. Southern against.

Dr. Rathe moved that the $5 application fee become effective January 1, 1956. Mr. Veirs seconded. Motion carried.

*Report of Director of National Meetings.* Dr. Nadler moved that the national organization will provide financial assistance to chapters sponsoring regional conferences. This assistance, in the form of a cash advance, must be repaid within thirty days after conclusion of the conference. The amount of the advance will be determined following a review of the request for such assistance, and a review of circumstances involved, such as: type of conference; program; date of the conference; and any other pertinent factors.

Any profit or loss resulting from such regional conferences will be split 50-50 by sponsoring chapter(s) and the national organization.

Approval for the establishment of national, regional, or local conferences will be made through the procedure to be established by the Director of National Meetings. This procedure, following clearance by the Executive Committee, will be published prior to July, 1956, and will become effective for any conference held after December 31, 1956. During the interim period October 22, 1955, to July 1, 1956, approval of financial support in connection with regional conferences, will be acted upon by the Executive Committee.

In the period October 22, 1955, to July 1, 1956, no definition of regional or local meetings will be made. In this period, the Executive Committee will make any necessary determinations in regard to whether any proposed conference is national, regional, or local in nature—and will determine the type and amount of assistance to be rendered by the National. Mr. Malcolm seconded the motion. After a considerable amount of discussion, the motion and second were withdrawn.

Dr. Nadler moved that the national organization may provide financial assistance to chapters sponsoring AIIE regional conferences. This assistance, in the form of a cash advance, must be repaid within thirty days after conclusion of the conference. The amount of the advance will be determined by the Executive Committee following a review of the request for such assistance, and a review of circumstances involved, such as: type of conference; program; date of the conference; and any other pertinent factors.

Any profit or loss resulting from such financially supported conferences will be split 50-50 by sponsoring chapter(s) and the national organization. Seconded by Colonel Egan. Motion carried.

The following motion was read from the 1953 Convention minutes:

"It was moved by Mr. Seinsheimer that all A. I. I. E. Chapters holding meetings, conferences, or clinics soliciting attendance beyond a 100 mile radius be required to clear such meetings through National Headquarters which should attempt to limit meetings to at least 30 days apart. The motion was seconded by Dale Jones and carried."

Mr. Malcolm then moved that the motion adopted at the 1953 Convention in Cincinnati be implemented through National Headquarters by the development of policies and procedures by the director of National Meetings. This to be non-applicable to conferences already scheduled and approved and to be effective July 1, 1956, in regard to new conferences. Seconded by Mr. Macy. Motion carried.

Mr. Southern read a letter from the Washington, D. C. Chapter requesting a cash advance in the matter of a loan for the publishing of their February 1955 Conference Proceedings.

Don Trenwith was instructed to reply to the Washington Chapter with regard to their request for assistance in publishing their proceedings of last February pointing out that the amount of financial assistance needed will have to be made known to National. Also, that this will have to be approved by the Executive Committee and that any such advance will be refunded to the National within six months of the date of the advance. We will assist in the publishing to the extent of multilithing typed copies and making arrangements for advertising in the *Journal*.

President Slagle had to leave the meeting at 6:20 P.M. to catch a plane. In the absence of President Slagle, Mr. Malcolm was appointed to act as chairman of the meeting.

Mr. Farnbacher read a letter from the Louisville Chapter offering the remainder of the copies of the 5th Annual Conference and Convention Proceedings at publication cost.

Colonel Egan suggested that we circulate a letter offering the publication to Libraries at cost.

Mr. Farnbacher moved that we propose to the Louisville Chapter that we have the Executive Secretary write a letter as stated by Colonel Egan to Libraries and other suitable prospects in an effort to aid them in selling these proceedings. Colonel Egan seconded and motion carried.

Don Trenwith was directed to contact the Louisville Chapter to give them the above information and to take steps to implement the contacting of the libraries and other prospects, if and when the subject proceedings are in the Headquarters office. The Louisville Chapter will receive the publication cost of each copy of the proceedings sold and paid for under the above action. Headquarters will not assume any financial responsibility for the proceedings except for copies sold.

*Jamshedpur Chapter.* Dr. Nadler moved that the Board of Trustees approve the concept of a separate India Institute of Industrial Engineers to be affiliated with the American Institute of Industrial Engineers. The Director of International Relations is to work with the Jamshedpur Chapter to determine the necessary arrangements and constitutional changes to recommend to AIIE. Seconded by Mr. Farnbacher. Motion carried.

*Journal.* Mr. Farnbacher moved that the Editorial Board be empowered to act on behalf of the Institute on matters concerning composition and format of the *Journal*. Seconded by Mr. Southern. Motion carried.

Mr. Macy moved the resolution that the Washington D. C. Chapter arrange or try to arrange the May 1956 Board of Trustees Meeting to be set at sometime to provide for a reasonable hour of termination. Seconded by Mr. Farnbacher. Motion carried.

*Report of Professional Relations Committee.* No report was given at this time since it was necessary for Dr. Rathe, Chairman of the Professional Relations Committee, to leave before this item was reached on the agenda.

*Adjournment.* 7:10 P.M.

*Next Board of Trustees Meeting.* May 18, 1956, Washington, D. C.

American Institute of Industrial Engineers, Inc.
145 N. High St.
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*(AIIE Long Range Planning Committee, Industrial Engineering Seminar, Cornell University, October 20-21, 1955)*